ASSINGMENT 2
MICROELECTRONIC CIRCUITS
DATE- 17/04/2022

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Question 1:-

1 Problem-1

Cascode MOSFET Amplifier Design with MOSFET cascode load: Design a Cascode amplifier using suitable topology to meet the specifications prescribed for you. VDD is 3.3V.

Design Specifications	Specifications desired	Specifications achieved
Voltage Gain	85± 5% (V/V)	81.1637 (V/V)
Current Gain	Not applicable	Not applicable
3-dB frequency	Not applicable	Not applicable
Pd	2.0± 5% (mW)	2.0702 (mW)

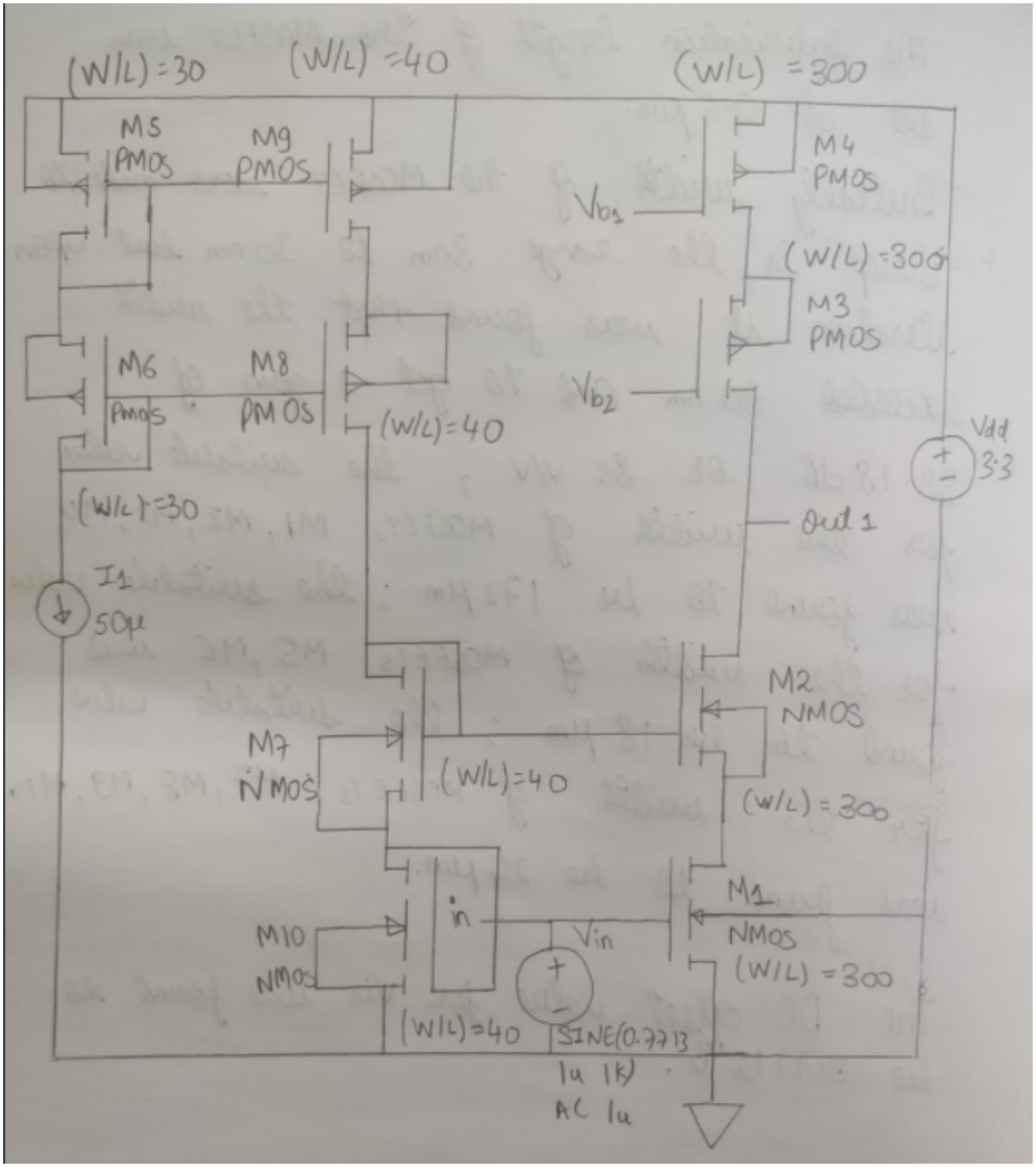
ID used for calculation:- 2020A3PS1237P
Sum of last 2 digits = 3+7 = 10
10 % 4 = 2 . Hence the required specifications were taken from Table 1.

The fabrication length of MOSFET was set at 0.6 micrometer.
Initially width of MOSFET was made to sweep in the range 3 nm to 30 nm but upon iteration it was found out that the width exceeded 30 nm and to get a gain of 38.18 dB or 81.1637 (V/V), the suitable value for the width of MOSFETs M1,M2,M3,M4 = 180 micrometer
the suitable value for the width of MOSFETs M7,M8,M9,M10 = 24 micrometer
the suitable value for the width of MOSFETs M5,M6 = 18 micrometer

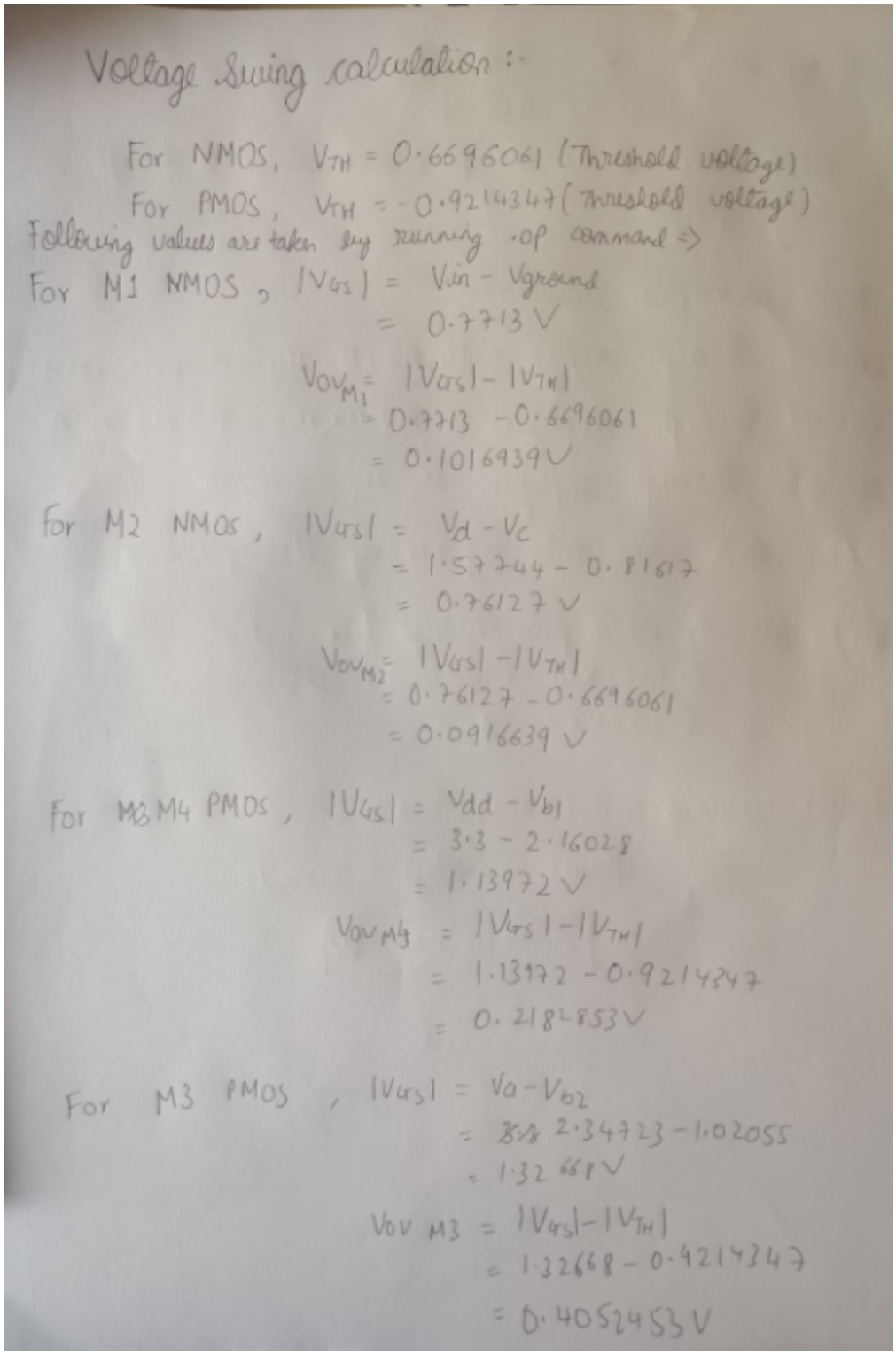
DC offset value for Vin was found to be 0.7713 V.

MOSFET Name	MOSFET w/l
M1	300
M2	300
M3	300
M4	300
M5	30
M6	30
M7	40
M8	40
M9	40
M10	40

Hand drawn circuit diagram-



Voltage Swing and Power Hand calculation-



Voltage Swing calculation :-

For NMOS, $V_{TH} = 0.6696061$ (Threshold voltage)

For PMOS, $V_{TH} = -0.9214347$ (Threshold voltage)

Following values are taken by running .op command =>

For M1 NMOS, $|V_{GS}| = V_{in} - V_{ground}$

$= 0.7713\ V$

$V_{OV_{M1}} = |V_{GS}| - |V_{TH}|$

$= 0.7713 - 0.6696061$

$= 0.1016939\ V$

For M2 NMOS, $|V_{GS}| = V_d - V_c$

$= 1.57744 - 0.81617$

$= 0.76127\ V$

$V_{OV_{M2}} = |V_{GS}| - |V_{TH}|$

$= 0.76127 - 0.6696061$

$= 0.0916639\ V$

For M3 M4 PMOS, $|V_{GS}| = V_{dd} - V_{b1}$

$= 3.3 - 2.16028$

$= 1.13972\ V$

$V_{OV_{M3}} = |V_{GS}| - |V_{TH}|$

$= 1.13972 - 0.9214347$

$= 0.2182853\ V$

For M3 PMOS, $|V_{GS}| = V_a - V_{b2}$

$= 3.3 - 2.34723 - 1.02055$

$= 1.32668\ V$

$V_{OV\ M3} = |V_{GS}| - |V_{TH}|$

$= 1.32668 - 0.9214347$

$= 0.4052453\ V$

Voltage swing $= V_{DD} - V_{OV_{M1}} - V_{OV_{M2}} - V_{OV_{M3}} - V_{OV_{M4}}$

$= \boxed{2.4831116\ V}$

which comes under the permissible range of voltage swing specified.

Power consumption calculation:-

Current through amplifiers M1, M2, M3, M4 = 0.00050981 A

Current through amplifiers M7, M8, M9, M10 = 6.7523×10^{-5} A

Current through amplifiers M5, M6 = 5×10^{-5} A

(These values were take by running the .op command)

Sum of currents which pass through V_{dd}

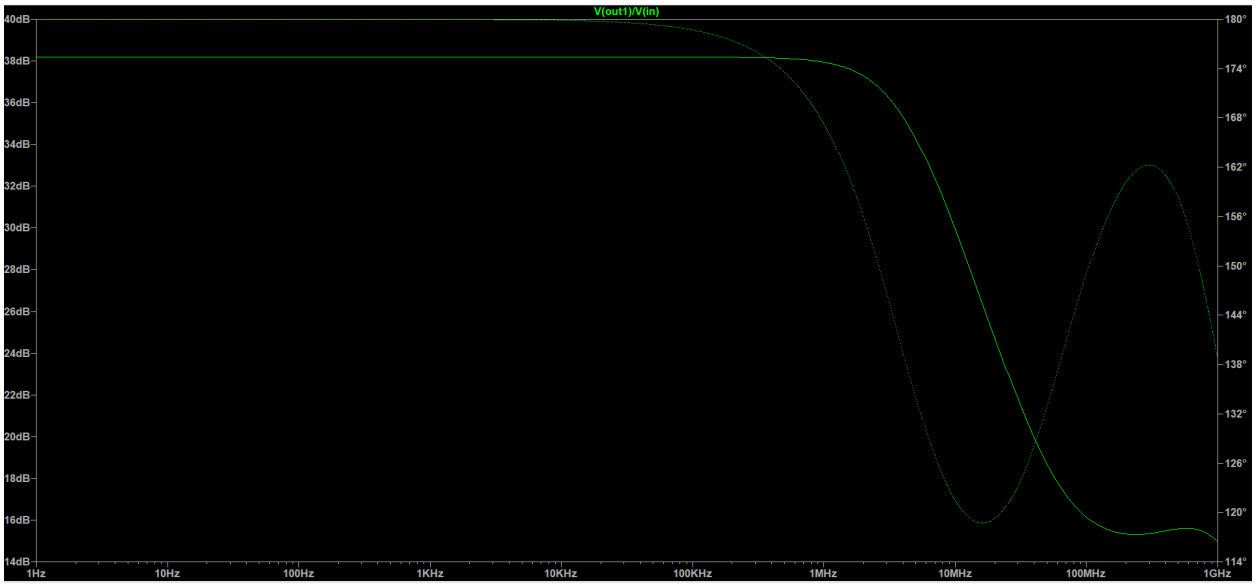
$= 6.7523 \times 10^{-5} + 5 \times 10^{-5} + 0.00050981$

$= 6.2733 \times 10^{-4}$ A

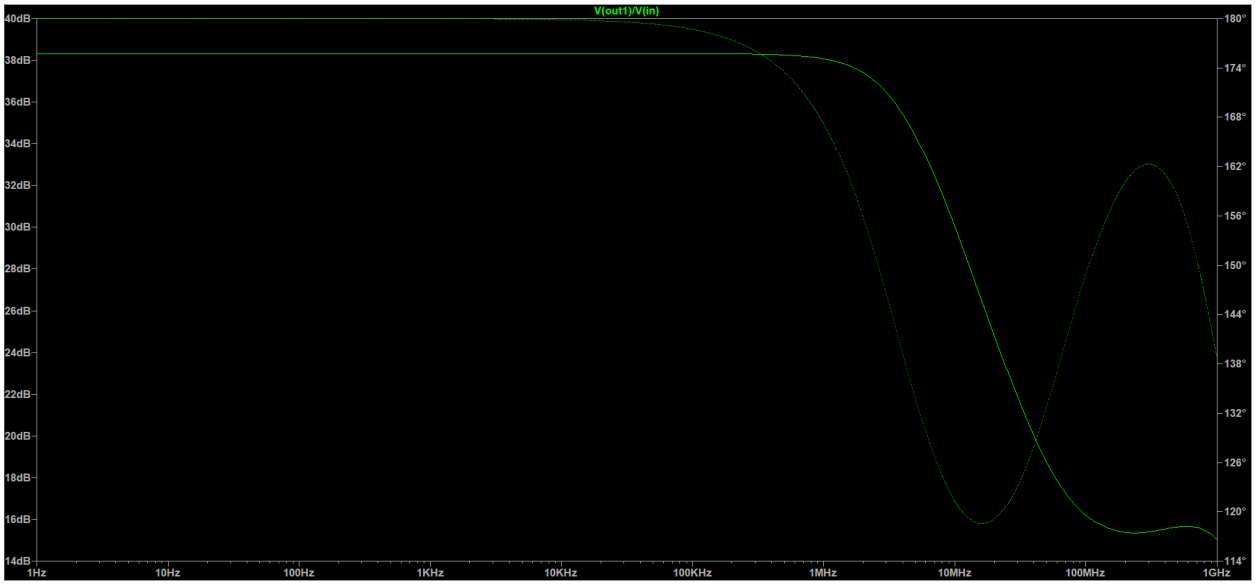
Power consumed $= 6.2733 \times 10^{-4} \times 3.3$

(Power = Voltage × Current)

$= \boxed{2.0702 \times 10^{-3}\ W}$

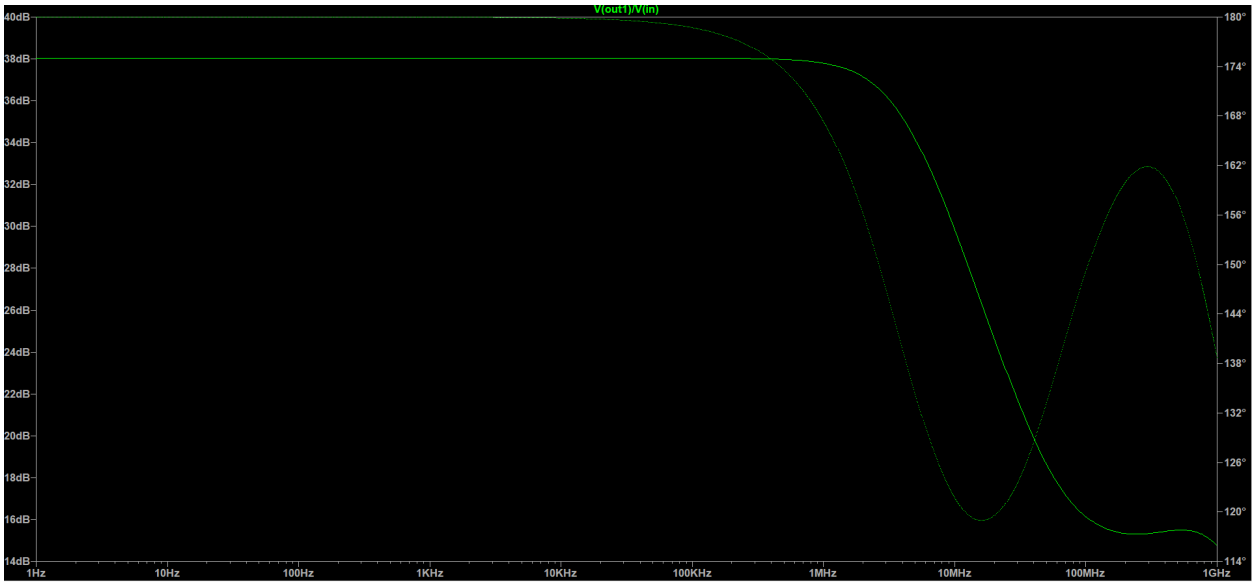


Bode plot with Vdd 3.3 V



Bode plot with Vdd 3.63 V

Gain when Vdd is changed to Vdd+10%(3.63 V) is 38.320195dB.



Bode plot with Vdd 2.97V

Gain when Vdd is changed to Vdd-10%(2.97 V) is 38.03741dB

* C:\Users\manah\Downloads\assignment2_mosfetcascode.asc

```
        --- Operating Point ---

V(c):           0.810876        voltage
V(in):          0.7713          voltage
V(out1):        1.92198         voltage
V(d):           1.57685         voltage
V(a):           2.03032         voltage
V(vb2):         0.690554        voltage
V(n001):        2.97            voltage
V(vb1):         1.83028         voltage
V(e):           0.788424        voltage
V(f):           1.86826         voltage
Id(M9):         6.72423e-005    device_current
Ig(M9):         -0              device_current
Ib(M9):         1.11174e-012    device_current
Is(M9):         -6.72423e-005   device_current
Id(M8):         6.72423e-005    device_current
Ig(M8):         -0              device_current
Ib(M8):         3.01415e-013    device_current
Is(M8):         -6.72423e-005   device_current
Id(M6):         5e-005          device_current
Ig(M6):         -0              device_current
Ib(M6):         1.14972e-012    device_current
Is(M6):         -5e-005         device_current
Id(M5):         5e-005          device_current
Ig(M5):         -0              device_current
Ib(M5):         1.14972e-012    device_current
Is(M5):         -5e-005         device_current
Id(M4):         0.000485579     device_current
Ig(M4):         -0              device_current
Ib(M4):         9.49681e-013    device_current
Is(M4):         -0.000485579    device_current
Id(M3):         0.000485578     device_current
Ig(M3):         -0              device_current
Ib(M3):         1.18186e-013    device_current
Is(M3):         -0.000485578    device_current
Id(M10):        6.72423e-005    device_current
Ig(M10):        0               device_current
Ib(M10):        -7.98424e-013   device_current
Is(M10):        -6.72423e-005   device_current
Id(M7):         6.72423e-005    device_current
Ig(M7):         0               device_current
Ib(M7):         -7.98424e-013   device_current
Is(M7):         -6.72423e-005   device_current
Id(M2):         0.000485579     device_current
Ig(M2):         0               device_current
Ib(M2):         -1.12111e-012   device_current
Is(M2):         -0.000485579    device_current
Id(M1):         0.000485579     device_current
Ig(M1):         0               device_current
Ib(M1):         -8.20876e-013   device_current
Is(M1):         -0.000485579    device_current
I(I1):          5e-005          device_current
I(Vin):         0               device_current
I(Vdd):         -0.000602821    device_current
```

.op command for q1

Question 2-

2 Problem-2

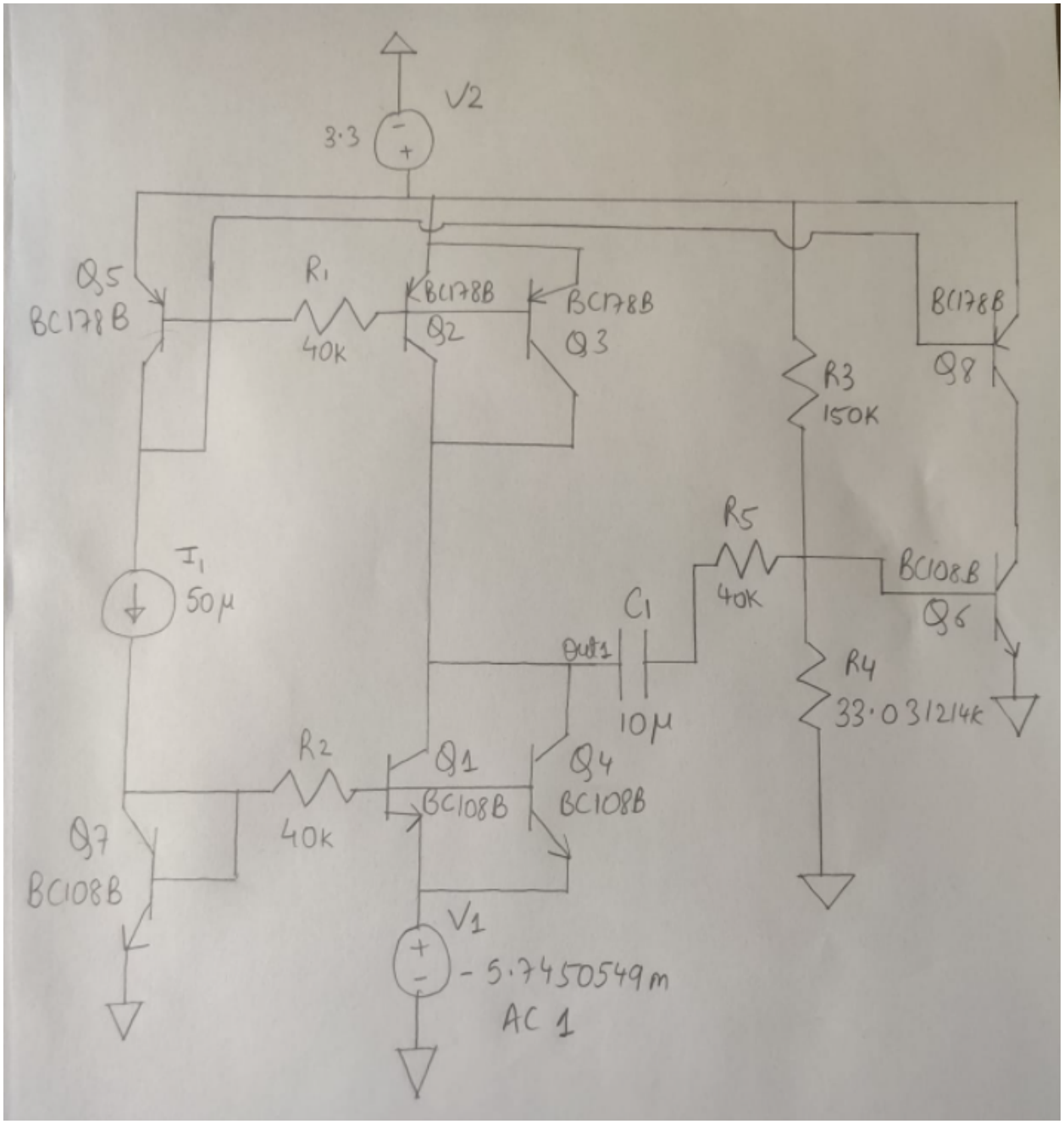
Design a (Common Base + Common Emitter) amplifier using suitable topology to meet the specifications prescribed for you. VDD is 3.3V.

Note : Other instructions remains same as previously given

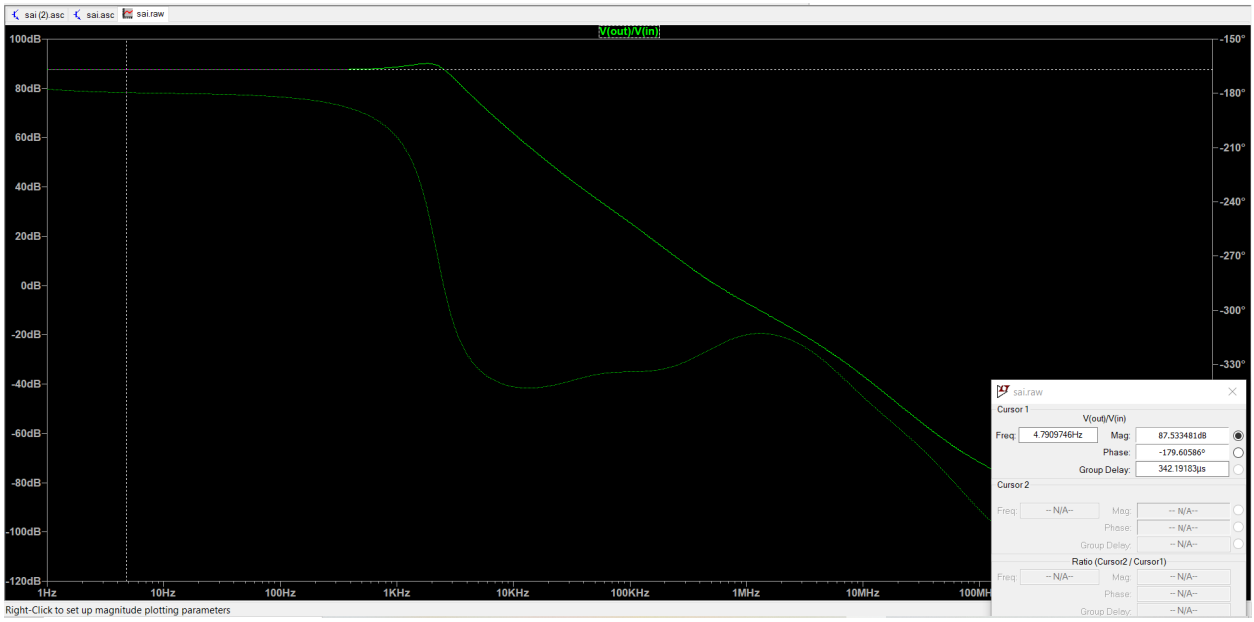
Design Specifications	Specifications desired	Specifications achieved
Voltage Gain	85± 5% (V/V)	87.5334
Current Gain	45± 5% (A/A)	24.64336
3-dB frequency	50K ± 5% (rad/s)	15.4506K (rad/s)
Pd	2.0± 5% (mW)	0.607 (mW)

ID used for calculation:- 2020A3PS1237P
Sum of last 2 digits = 3+7 = 10
10 % 4 = 2 . Hence the required specifications were taken from Table 1.

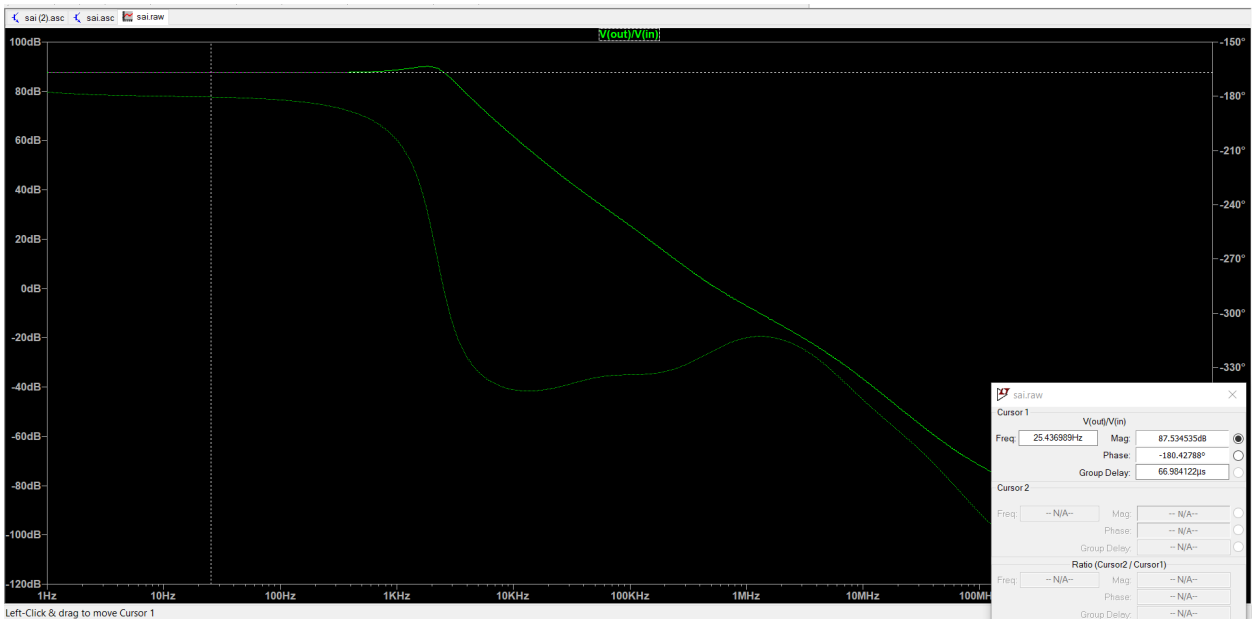
Hand drawn circuit for question2-



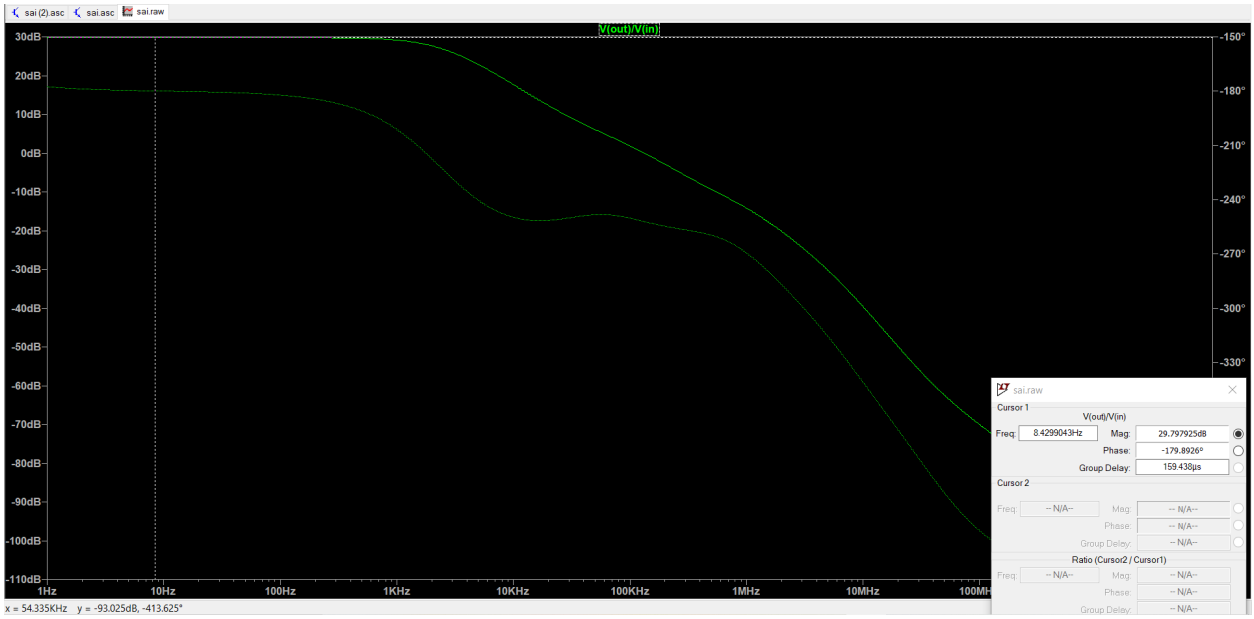
Bode plot for voltage gain for Vdd 3.3 V



Bode plot for current gain for Vdd 3.3 V



Bode plot for voltage gain with Vdd 3.63 V
Voltage gain when Vdd is changed to Vdd+10%(3.63 V) is 29.797925dB.



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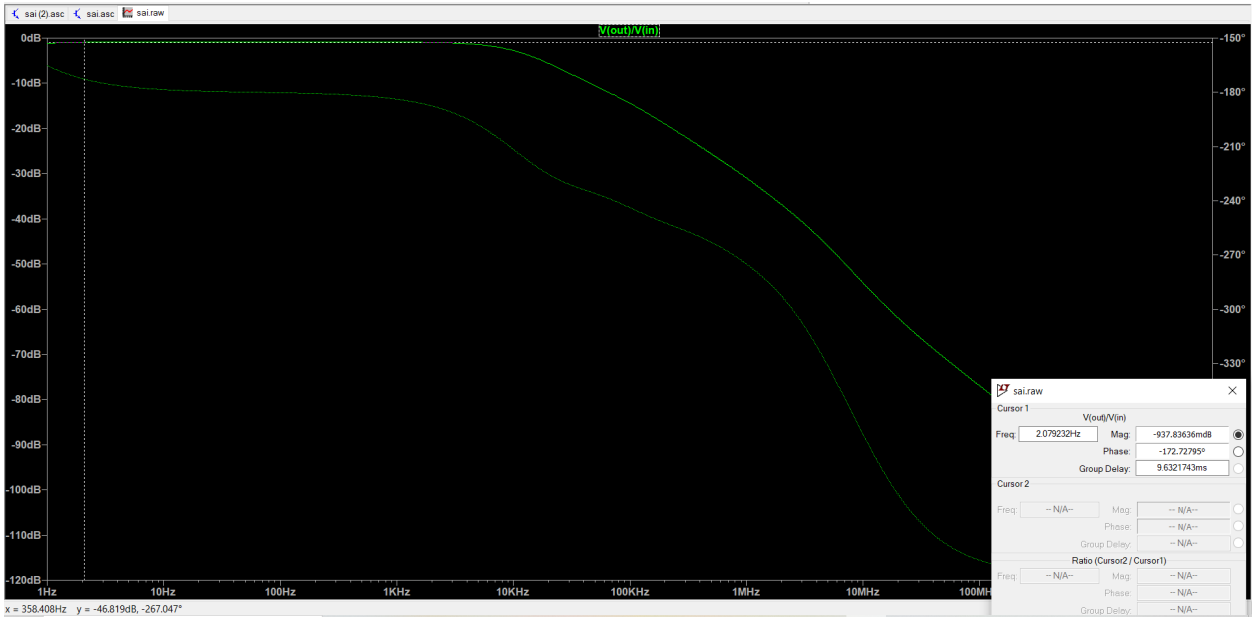
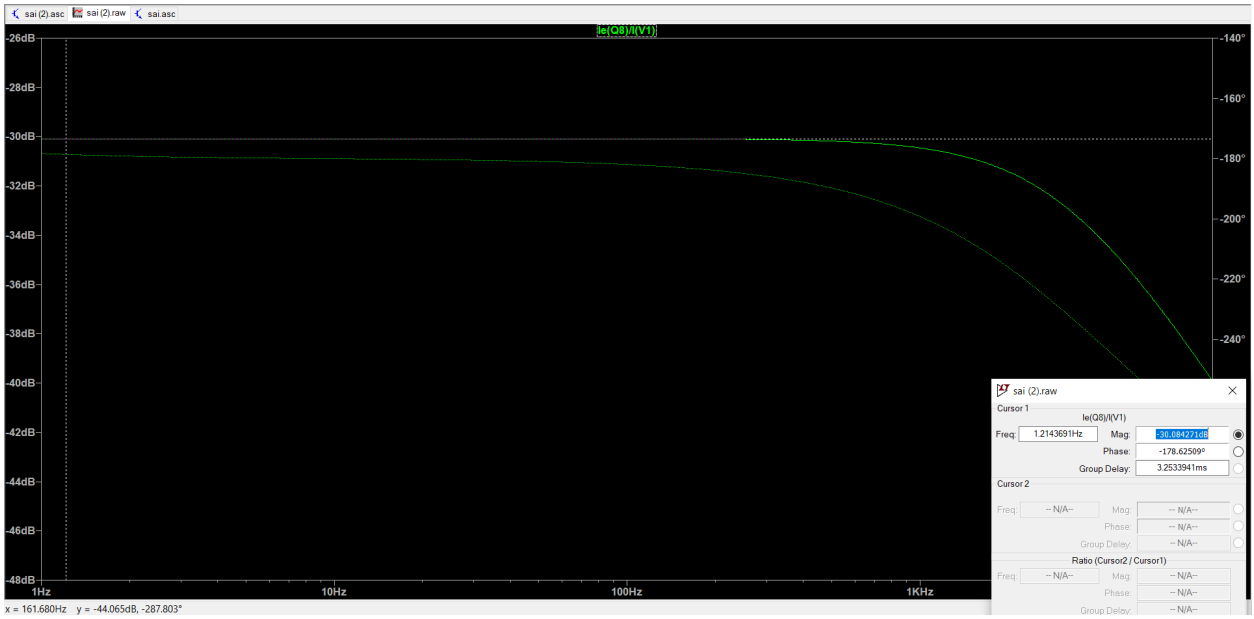
Bode plot for voltage gain with Vdd 2.97 V

Voltage gain when Vdd is changed to Vdd-10%(2.97 V) is -937.83636mdB.



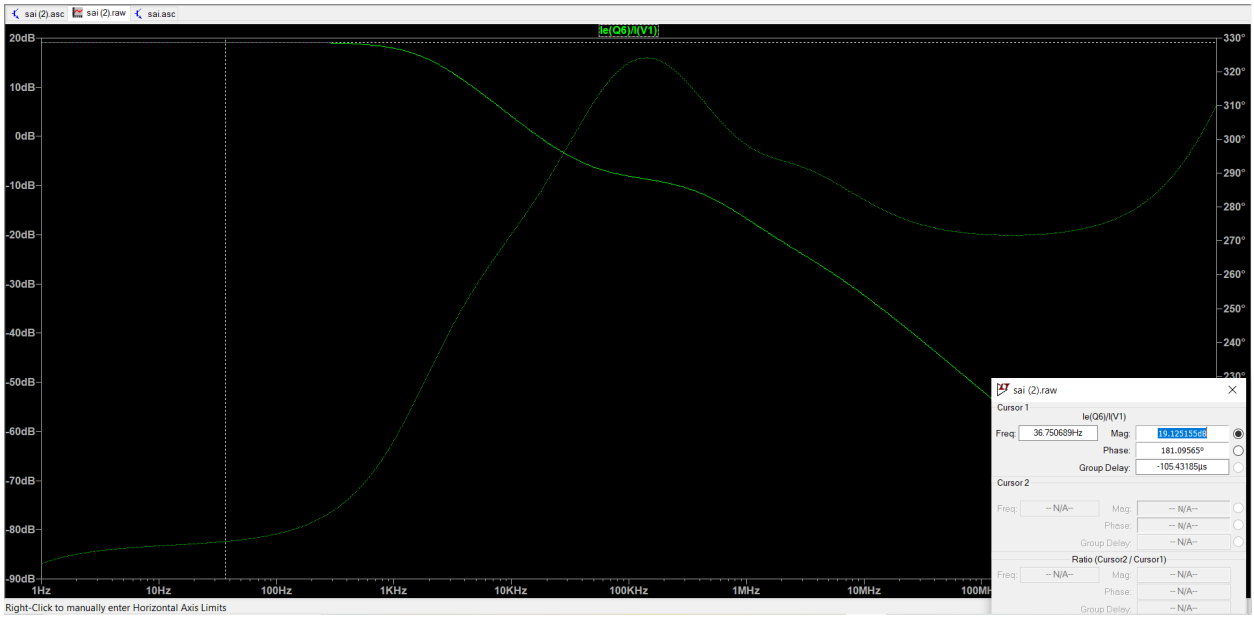
Bode plot for current gain with Vdd 3.63 V.

Current gain when Vdd is changed to Vdd+10%(3.3 V) is -30.084271dB.

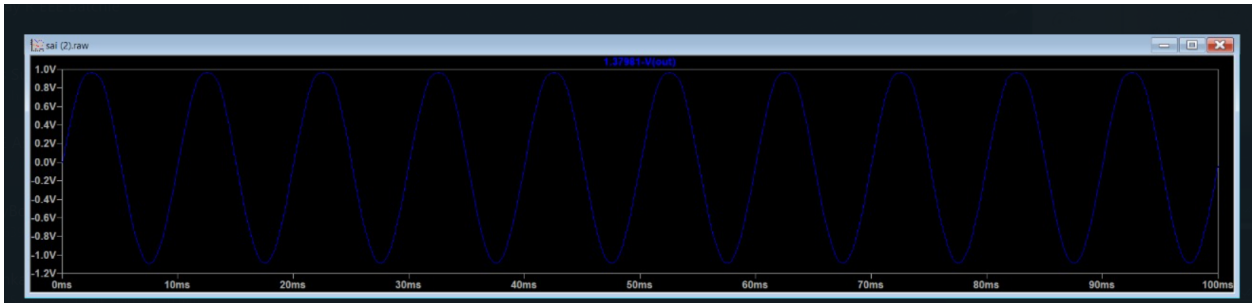


Bode plot for current gain with Vdd 2.97 V.

Current gain when Vdd is changed to Vdd-10%(2.97 V) is 19.125155dB.



Voltage swing achieved from SPICE = 2.0312 V



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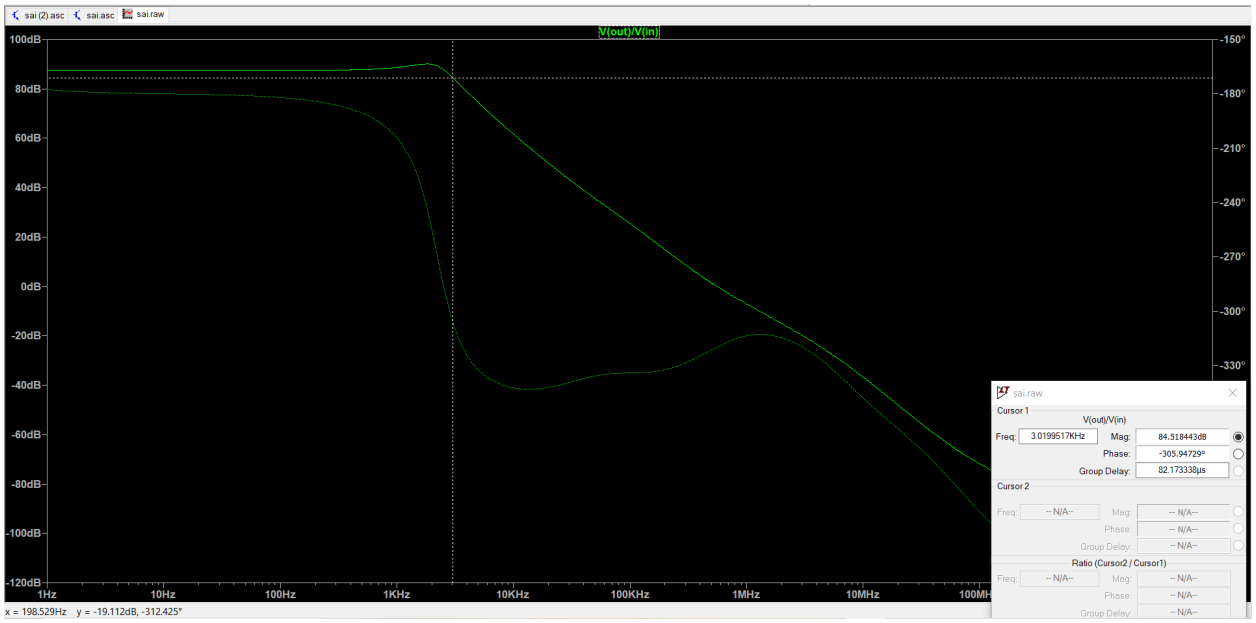
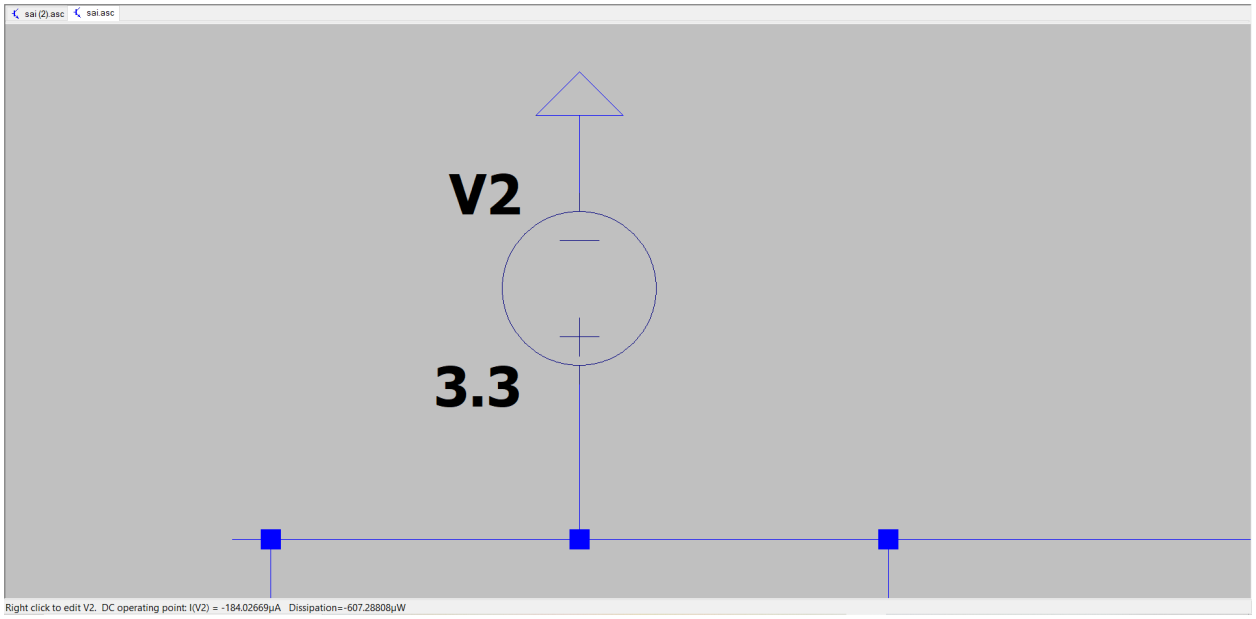
3 dB frequency for Vdd 3.3 V = 3.013006KHz = 18.921 K rad/s



Power dissipation = 0.607 mW



.op command for question 2

* C:\Users\manah\Downloads\sai.asc

```
       --- Operating Point ---

V(out1):        1.52583        voltage
V(n006):        0.569155       voltage
V(n009):        -0.00574505    voltage
V(n003):        2.82576        voltage
V(n001):        3.3            voltage
V(n002):        2.81371        voltage
V(n005):        0.586298       voltage
V(n004):        1.40044        voltage
V(n008):        0.587096       voltage
V(n007):        0.587096       voltage
Ic(Q8):         -5.15048e-005  device_current
Ib(Q8):         -2.28588e-007  device_current
Ie(Q8):         5.17333e-005   device_current
Ic(Q3):         -3.2218e-005   device_current
Ib(Q3):         -1.50573e-007  device_current
Ie(Q3):         3.23685e-005   device_current
Ic(Q5):         -4.92399e-005  device_current
Ib(Q5):         -2.30346e-007  device_current
Ie(Q5):         4.94703e-005   device_current
Ic(Q2):         -3.2218e-005   device_current
Ib(Q2):         -1.50573e-007  device_current
Ie(Q2):         3.23685e-005   device_current
Ic(Q6):         5.15048e-005   device_current
Ib(Q6):         3.12054e-007   device_current
Ie(Q6):         -5.18168e-005  device_current
Ic(Q4):         3.2218e-005    device_current
Ib(Q4):         2.14286e-007   device_current
Ie(Q4):         -3.24322e-005  device_current
Ic(Q7):         4.92668e-005   device_current
Ib(Q7):         3.04607e-007   device_current
Ie(Q7):         -4.95714e-005  device_current
Ic(Q1):         3.2218e-005    device_current
Ib(Q1):         2.14286e-007   device_current
Ie(Q1):         -3.24322e-005  device_current
I(C1):          9.38731e-018   device_current
I(I1):          5e-005         device_current
I(R5):          -9.38694e-018  device_current
I(R4):          1.7774e-005    device_current
I(R3):          1.8086e-005    device_current
I(R2):          -4.28571e-007  device_current
I(R1):          3.01147e-007   device_current
I(V2):          -0.000184027   device_current
I(V1):          6.48645e-005   device_current
```

Netlist for question 1

```
M1 c in 0 0 NMOS l=0.6u w=172u
M2 out1 d c c NMOS l=0.6u w=172u
M3 a Vb2 out1 a PMOS l=0.6u w=172u
M4 N001 Vb1 a N001 PMOS l=0.6u w=172u
Vdd N001 0 3.3
Vin in 0 SINE(0.7713 1u 1k) AC 1u
M5 N001 Vb1 Vb1 N001 PMOS l=0.6u w=18u
M6 Vb1 Vb2 Vb2 Vb1 PMOS l=0.6u w=18u
M7 d d e e NMOS l=0.6u w=24u
I1 Vb2 0 50µ
M8 f Vb2 d f PMOS l=0.6u w=24u
M9 N001 Vb1 f N001 PMOS l=0.6u w=24u
M10 e e 0 0 NMOS l=0.6u w=24u
.model NMOS NMOS
.model PMOS PMOS
.lib C:\Users\Sai Kartik\OneDrive - BIRLA INSTITUTE OF TECHNOLOGY and
SCIENCE\Documents\LTspiceXVII\lib\cmp\standard.mos
.MODEL NMOS NMOS (                              LEVEL   = 8
+VERSION = 3.1          TNOM    = 27            TOX     = 1.39E-8
+XJ      = 1.5E-7       NCH     = 1.7E17        VTH0    = 0.6696061
+K1      = 0.8351612    K2      = -0.0839158    K3      = 23.1023856
+K3B     = -7.6841108   W0      = 1E-8          NLX     = 1E-9
+DVT0W   = 0            DVT1W   = 0             DVT2W   = 0
+DVT0    = 2.9047241    DVT1    = 0.4302695     DVT2    = -0.134857
+U0      = 458.439679   UA      = 1E-13         UB      = 1.485499E-18
+UC      = 1.629939E-11 VSAT    = 1.643993E5    A0      = 0.6103537
+AGS     = 0.1194608    B0      = 2.674756E-6   B1      = 5E-6
+KETA    = -2.640681E-3 A1      = 8.219585E-5   A2      = 0.3564792
+RDSW    = 1.387108E3   PRWG    = 0.0299916     PRWB    = 0.0363981
+WR      = 1            WINT    = 2.472348E-7   LINT    = 3.597605E-8
+XL      = 0            XW      = 0             DWG     = -1.287163E-8
+DWB     = 5.306586E-8  VOFF    = 0             NFACTOR = 0.8365585
+CIT     = 0            CDSC    = 2.4E-4        CDSCD   = 0
+CDSCB   = 0            ETA0    = 0.0246738     ETAB    = -1.406123E-3
+DSUB    = 0.2543458    PCLM    = 2.5945188     PDIBLC1 = -0.4282336
+PDIBLC2 = 2.311743E-3  PDIBLCB = -0.0272914    DROUT   = 0.7283566
+PSCBE1  = 5.598623E8   PSCBE2  = 5.461645E-5   PVAG    = 0
+DELTA   = 0.01         RSH     = 81.8          MOBMOD  = 1
+PRT     = 8.621        UTE     = -1            KT1     = -0.2501
+KT1L    = -2.58E-9     KT2     = 0             UA1     = 5.4E-10
+UB1     = -4.8E-19     UC1     = -7.5E-11      AT      = 1E5
+WL      = 0            WLN     = 1             WW      = 0
```

```
+WWN     = 1            WWL     = 0            LL      = 0
+LLN     = 1            LW      = 0            LWN     = 1
+LWL     = 0            CAPMOD  = 2            XPART   = 0.5
+CGDO    = 2E-10        CGSO    = 2E-10        CGBO    = 1E-9
+CJ      = 4.197772E-4  PB      = 0.99         MJ      = 0.4515044
+CJSW    = 3.242724E-10 PBSW    = 0.1          MJSW    = 0.1153991
+CJSWG   = 1.64E-10     PBSWG   = 0.1          MJSWG   = 0.1153991
+CF      = 0            PVTH0   = 0.0585501    PRDSW   = 133.285505
+PK2     = -0.0299638   WKETA   = -0.0248758   LKETA   = 1.173187E-3
+AF      = 1            KF      = 0)
*
* .ac dec 100 1 1G
* .step param x 0.5u 13.5u 0.5u
.op
* .step param v 0.7 0.8 0.0001
.MODEL PMOS PMOS (                             LEVEL   = 8
+VERSION = 3.1          TNOM    = 27           TOX     = 1.39E-8
+XJ      = 1.5E-7       NCH     = 1.7E17       VTH0    = -0.9214347
+K1      = 0.5553722    K2      = 8.763328E-3  K3      = 6.3063558
+K3B     = -0.6487362   W0      = 1.280703E-8  NLX     = 2.593997E-8
+DVT0W   = 0            DVT1W   = 0            DVT2W   = 0
+DVT0    = 2.5131165    DVT1    = 0.5480536    DVT2    = -0.1186489
+U0      = 212.0166131  UA      = 2.807115E-9  UB      = 1E-21
+UC      = -5.82128E-11 VSAT    = 1.713601E5   A0      = 0.8430019
+AGS     = 0.1328608    B0      = 7.117912E-7  B1      = 5E-6
+KETA    = -3.674859E-3 A1      = 4.77502E-5   A2      = 0.3
+RDSW    = 2.837206E3   PRWG    = -0.0363908   PRWB    = -1.016722E-5
+WR      = 1            WINT    = 2.838038E-7  LINT    = 5.528807E-8
+XL      = 0            XW      = 0            DWG     = -1.606385E-8
+DWB     = 2.266386E-8  VOFF    = -0.0558512   NFACTOR = 0.9342488
+CIT     = 0            CDSC    = 2.4E-4       CDSCD   = 0
+CDSCB   = 0            ETA0    = 0.3251882    ETAB    = -0.0580325
+DSUB    = 1            PCLM    = 2.2409567    PDIBLC1 = 0.0411445
+PDIBLC2 = 3.355575E-3  PDIBLCB = -0.0551797   DROUT   = 0.2036901
+PSCBE1  = 6.44809E9    PSCBE2  = 6.300848E-10 PVAG    = 0
+DELTA   = 0.01         RSH     = 101.6        MOBMOD  = 1
+PRT     = 59.494       UTE     = -1           KT1     = -0.2942
+KT1L    = 1.68E-9      KT2     = 0            UA1     = 4.5E-9
+UB1     = -6.3E-18     UC1     = -1E-10       AT      = 1E3
+WL      = 0            WLN     = 1            WW      = 0
+WWN     = 1            WWL     = 0            LL      = 0
+LLN     = 1            LW      = 0            LWN     = 1
+LWL     = 0            CAPMOD  = 2            XPART   = 0.5
+CGDO    = 2.9E-10      CGSO    = 2.9E-10      CGBO    = 1E-9
+CJ      = 7.235528E-4  PB      = 0.9527355    MJ      = 0.4955293
+CJSW    = 2.692786E-10 PBSW    = 0.99         MJSW    = 0.2958392
```

```
+CJSWG   = 6.4E-11        PBSWG   = 0.99          MJSWG   = 0.2958392
+CF      = 0              PVTH0   = 5.98016E-3    PRDSW   = 14.8598424
+PK2     = 3.73981E-3     WKETA   = 5.292165E-3   LKETA   = -4.205905E-3
+AF      = 1              KF      = 0)
* power consumed = 1.93mW
* Voltage gain of the circuit= 38.18dB
* required swing = 2.66V
.backanno
.end
```

Netlist for question 2

```
Q1 out1 N005 N008 0 BC108B
Q2 out1 N003 N001 0 BC178B
V1 N008 0 -5.7450549m AC 1
R1 N003 N002 40k
Q5 N002 N002 N001 0 BC178B
I1 N002 N004 50µ
Q7 N004 N004 0 0 BC108B
R2 N005 N004 40k
V2 N001 0 3.3
Q3 out1 N003 N001 0 BC178B
Q4 out1 N005 N008 0 BC108B
Q6 out N007 0 0 BC108B
Q8 out N002 N001 0 BC178B
R3 N001 N007 150k
R4 N007 0 33.031214K
R5 N007 N006 40k
C1 out1 N006 10µ
C2 out 0 100f
.model NPN NPN
.model PNP PNP
.lib C:\Users\Sai Kartik\OneDrive - BIRLA INSTITUTE OF TECHNOLOGY and
SCIENCE\Documents\LTspiceXVII\lib\cmp\standard.bjt
.model BC107A   NPN(Is=7.049f Xti=3 Eg=1.11 Vaf=116.3 Bf=375.5 Ise=7.049f
+               Ne=1.281 Ikf=4.589 Nk=.5 Xtb=1.5 Br=2.611 Isc=121.7p Nc=1.865
+               Ikr=5.313 Rc=1.464 Cjc=5.38p Mjc=.329 Vjc=.6218 Fc=.5 Cje=11.5p
+               Mje=.2717 Vje=.5 Tr=10n Tf=451p Itf=6.194 Xtf=17.43 Vtf=10)
.model BC107B   NPN(Is=7.049f Xti=3 Eg=1.11 Vaf=59.59 Bf=381.7 Ise=59.74f
+               Ne=1.522 Ikf=3.289 Nk=.5 Xtb=1.5 Br=2.359 Isc=192.9p Nc=1.954
+               Ikr=7.807 Rc=1.427 Cjc=5.38p Mjc=.329 Vjc=.6218 Fc=.5 Cje=11.5p
+               Mje=.2718 Vje=.5 Tr=10n Tf=438p Itf=5.716 Xtf=14.51 Vtf=10)
.model BC108A   NPN(Is=7.049f Xti=3 Eg=1.11 Vaf=116.3 Bf=375.5 Ise=7.049f
+               Ne=1.281 Ikf=4.589 Nk=.5 Xtb=1.5 Br=2.611 Isc=121.7p Nc=1.865
```

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+            Ikr=5.313 Rc=1.464 Cjc=5.38p Mjc=.329 Vjc=.6218 Fc=.5 Cje=11.5p
+            Mje=.2717 Vje=.5 Tr=10n Tf=451p Itf=6.194 Xtf=17.43 Vtf=10)
.model BC108B   NPN(Is=7.049f Xti=3 Eg=1.11 Vaf=59.59 Bf=381.7 Ise=59.74f
+            Ne=1.522 Ikf=3.289 Nk=.5 Xtb=1.5 Br=2.359 Isc=192.9p Nc=1.954
+            Ikr=7.807 Rc=1.427 Cjc=5.38p Mjc=.329 Vjc=.6218 Fc=.5 Cje=11.5p
+            Mje=.2718 Vje=.5 Tr=10n Tf=438p Itf=5.716 Xtf=14.51 Vtf=10)
.model BC178B   PNP(Is=336.7f Xti=3 Eg=1.11 Vaf=30.75 Bf=271.9 Ise=2.821p
+            Ne=1.925 Ikf=.2462 Nk=.5416 Xtb=1.5 Br=3.009 Isc=1.753n
+            Nc=2.075 Ikr=8.143 Rc=1.803 Cjc=11p Mjc=.2223 Vjc=.5 Fc=.5
+            Cje=33p Mje=.3333 Vje=.5 Tr=10n Tf=846p Itf=1.546 Xtf=18.27
+            Vtf=10)
.model BC179A   PNP(Is=336.7f Xti=3 Eg=1.11 Vaf=44.61 Bf=187 Ise=336.8f
+            Ne=1.459 Ikf=.2059 Nk=.5081 Xtb=1.5 Br=4.068 Isc=1.121n
+            Nc=1.953 Ikr=10.05 Rc=1.86 Cjc=11p Mjc=.2223 Vjc=.5 Fc=.5
+            Cje=33p Mje=.3333 Vje=.5 Tr=10n Tf=845.5p Itf=1.701 Xtf=19.04
+            Vtf=10)
;dc v3 -5 5 0.001
.ac dec 1000 1 10G
.op
;.step param r 30k 1000k 1k
.backanno
.end
```