EE352 HW2 Solutions

1.) a.) DC node voltages and branch currents hand calculated (see schematic below; hand calculated values are labeled and circled).

b.) AC Hand Analysis:

$g_{m1} = g_{m2} = \frac{I_C}{V_T} = 2mA/V^2$

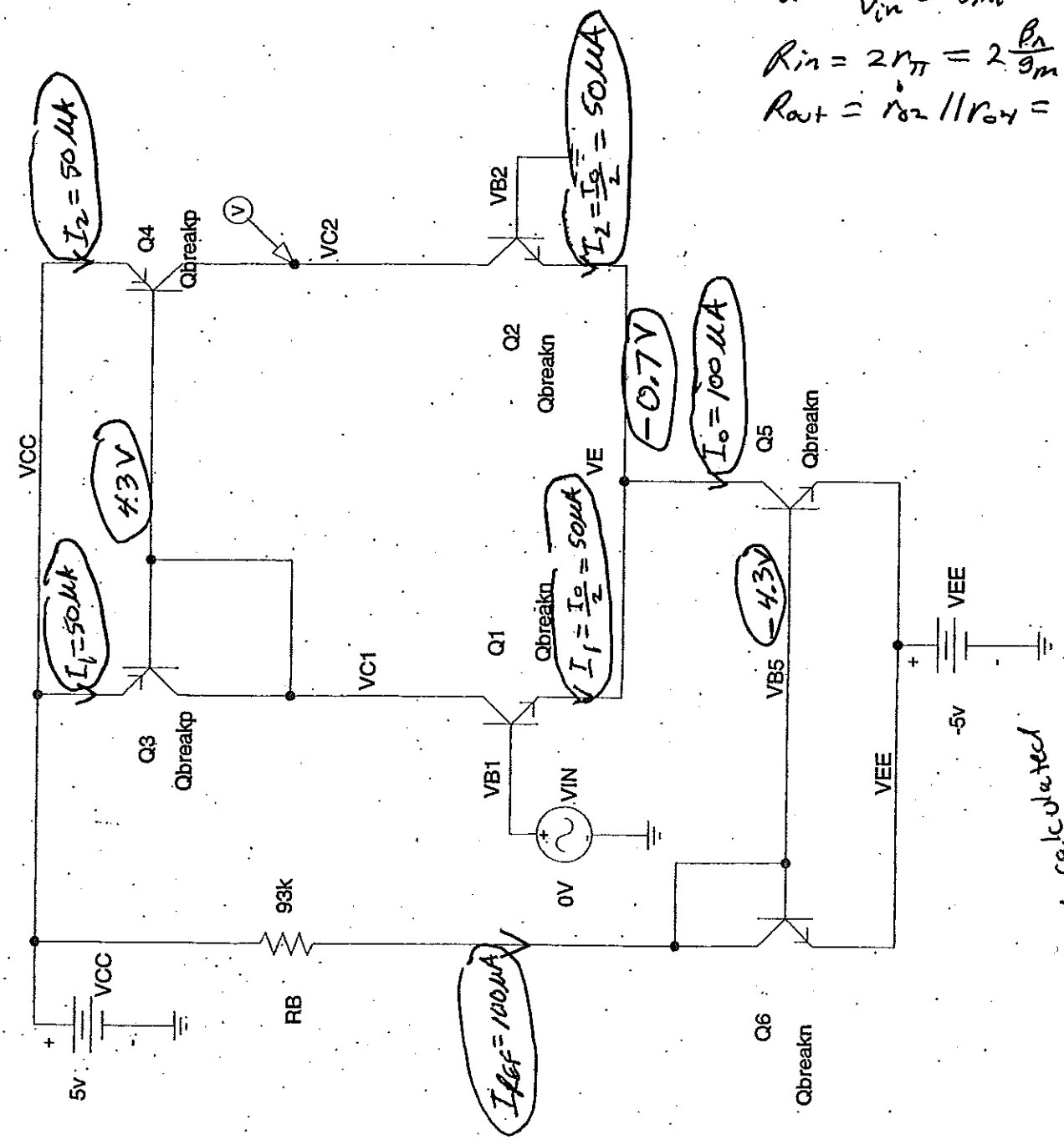
$r_{o2} = \frac{V_{Ap}}{I_2} = \frac{80}{50\mu A} = 1.6 M\Omega$

$r_{o4} = \frac{V_{An}}{I_2} = \frac{130}{50\mu A} = 2.6 M\Omega$ (1981 V&H)

$A_d = \frac{V_{c2}}{V_{in}} = g_{m1}(r_{o2} \| r_{o4}) =$

$R_{in} = 2r_\pi = 2\frac{\beta_n}{g_m} =$ (150 KΩ)

$R_{out} = r_{o2} \| r_{o4} =$ (990 KΩ)



DC, hand-calculated Node Voltage and Branch Currents shown as circled.

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**** 01/30/102 10:07:45 ******* PSpice 6.2 (April 1995) ******* ID# 83989 ****
 * /usr1.c/oster/pspice/ee352/spring98/hw2/hw2a.sch
 ****     CIRCUIT DESCRIPTION
********************************************************************************
* Schematics Version 6.2 - April 1995
* Wed Jan 30 10:07:40 2002
** Analysis setup **
.DC LIN V_VIN -.1 .1 .001
.TF V([VC2]) V_VIN
.OP
.LIB hw2a.lib
* From [SCHEMATICS NETLIST] section of msim.ini:
.lib nom.lib
.INC "hw2a.net"
**** INCLUDING hw2a.net ****
* Schematics Netlist *
Q_Q1           VC1 VB1 VE Qbreakn
Q_Q2           VC2 0 VE Qbreakn
Q_Q3           VC1 VC1 VCC Qbreakp
Q_Q4           VC2 VC1 VCC Qbreakp
V_VCC           VCC 0 5v
V_VEE           VEE 0 -5v
V_VIN           VB1 0 DC 0V AC 0V
Q_Q5           VE VB5 VEE Qbreakn
Q_Q6           VB5 VB5 VEE Qbreakn
R_RB           VB5 VCC  93k
.probe
.END

 ****     BJT MODEL PARAMETERS
********************************************************************************
               Qbreakp          Qbreakn
               PNP              NPN
          IS   100.000000E-18   100.000000E-18
          BF   100              150
          NF     1                1
         VAF    80              130
          BR     1                1
          NR     1                1

 ****     SMALL SIGNAL BIAS SOLUTION       TEMPERATURE =   27.000 DEG C
********************************************************************************
 NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE
(   VE)    -.6961  (  VB1)     0.0000  (  VB5)   -4.2857  (  VC1)    4.3035
(  VC2)    3.3083  (  VCC)     5.0000  (  VEE)   -5.0000

    VOLTAGE SOURCE CURRENTS
    NAME         CURRENT
    V_VCC       -2.004E-04
    V_VEE        2.011E-04
    V_VIN       -3.258E-07

    TOTAL POWER DISSIPATION   2.01E-03  WATTS

 ****     OPERATING POINT INFORMATION      TEMPERATURE =   27.000 DEG C
********************************************************************************

**** BIPOLAR JUNCTION TRANSISTORS
NAME            Q_Q1          Q_Q2          Q_Q3          Q_Q4          Q_Q5
MODEL           Qbreakn       Qbreakn       Qbreakp       Qbreakp       Qbreakn
IB              3.26E-07      3.26E-07     -4.95E-07     -4.95E-07      6.57E-07
IC              5.05E-05      5.01E-05     -4.95E-05     -5.01E-05      1.01E-04
VBE             6.96E-01      6.96E-01     -6.96E-01     -6.96E-01      7.14E-01
VBC            -4.30E+00     -3.31E+00      0.00E+00      9.95E-01     -3.59E+00
VCE             5.00E+00      4.00E+00     -6.96E-01     -1.69E+00      4.30E+00
BETADC          1.55E+02      1.54E+02      1.00E+02      1.01E+02      1.54E+02
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1. .out file

GM	1.95E-03	1.94E-03	1.91E-03	1.94E-03	3.91E-03
RPI	7.94E+04	7.94E+04	5.23E+04	5.23E+04	3.94E+04
RX	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RO	2.66E+06	2.66E+06	1.62E+06	1.62E+06	1.32E+06
CBE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBX	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CJS	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BETAAC	1.55E+02	1.54E+02	1.00E+02	1.01E+02	1.54E+02
FT	3.11E+16	3.08E+16	3.04E+16	3.08E+16	6.23E+16

NAME	Q_Q6
MODEL	Qbreakn
IB	6.57E-07
IC	9.85E-05
VBE	7.14E-01
VBC	0.00E+00
VCE	7.14E-01
BETADC	1.50E+02
GM	3.81E-03
RPI	3.94E+04
RX	0.00E+00
RO	1.32E+06
CBE	0.00E+00
CBC	0.00E+00
CBX	0.00E+00
CJS	0.00E+00
BETAAC	1.50E+02
FT	6.06E+16

**** SMALL-SIGNAL CHARACTERISTICS

V(VC2)/V_VIN = 1.947E+03

INPUT RESISTANCE AT V_VIN = 2.549E+05

OUTPUT RESISTANCE AT V(VC2) = 1.005E+06

JOB CONCLUDED

TOTAL JOB TIME 1.55

(2.) a.) DC node voltages and branch currents hand calculation (See schematic below; hand calculated DC values are labelled and circled).

$I_1 = 100\mu A = K_n (V_{GS} - V_{tn})^2 = 250\mu A/V^2 [(0 - V_S) - 1]^2 \Rightarrow V_S = -1.63V$

$I_2 = 100\mu A = K_p (V_{SG} - |V_{tp}|)^2 = 200\mu A/V^2 [(V_{CC} - V_{D1}) - 1.5]^2 \Rightarrow V_{D1} = 2.79V$

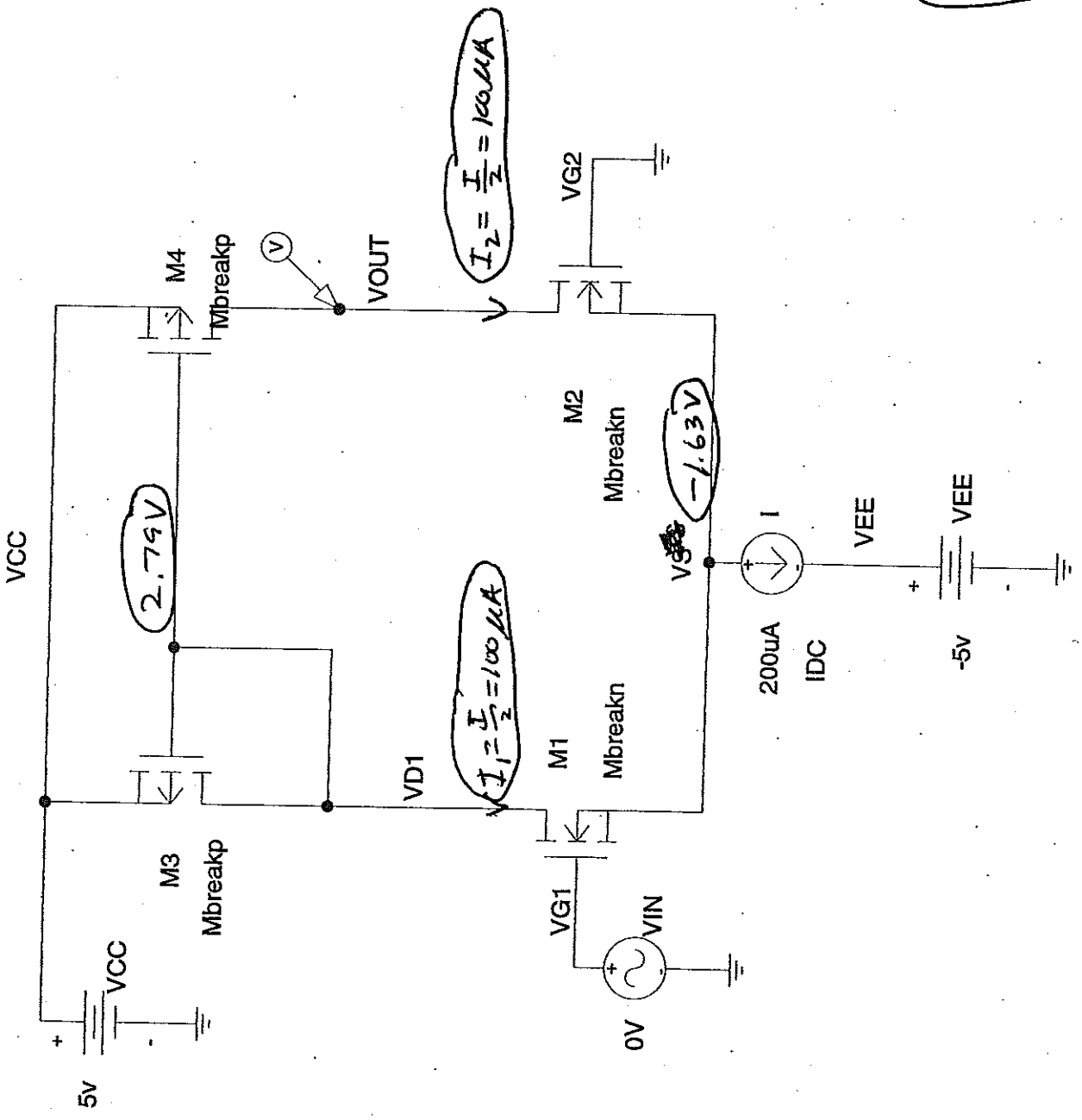
b.) AC Hand Analysis: $g_{m1} = \sqrt{4 K_n I_1} = .316\ mA/V^2$

$r_{o2} = \frac{1}{\lambda_2 I_2} = 500K\Omega$; $r_{o4} = \frac{1}{\lambda_4 I_2} = 200K$

$A_d = g_{m1}(r_{o2} \| r_{o4}) =$ (45.1 V/V)

$R_{in} =$ (∞)

$R_{out} = r_{o2} \| r_{o4} =$ (143 KΩ)



DC hand-calculated node voltages and branch currents shown above as circled

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**** 02/01/102 14:57:17 ******* PSpice 6.2 (April 1995) ******* ID# 83989 ****
 ****     CIRCUIT DESCRIPTION
********************************************************************************
* Schematics Version 6.2 - April 1995
* Fri Feb  1 14:57:12 2002
** Analysis setup **
.DC LIN V_VIN -.1 .1 .001
.TF V([VOUT]) V_VIN
.OP
.LIB hw2b.lib
* From [SCHEMATICS NETLIST] section of msim.ini:
.lib nom.lib
.INC "hw2b.net"
**** INCLUDING hw2b.net ****
* Schematics Netlist *
V_VCC           VCC 0 5v
V_VEE           VEE 0 -5v
V_VIN           VG1 0 DC 0V AC 0V
M_M1           VD1 VG1 VS VS Mbreakn
M_M2           VOUT 0 VS VS Mbreakn
M_M4           VOUT VD1 VCC VCC Mbreakp
M_M3           VD1 VD1 VCC VCC Mbreakp
I_I           VS VEE DC 200uA
.probe
.END

 ****     MOSFET MODEL PARAMETERS
********************************************************************************
                 Mbreakn          Mbreakp
                 NMOS             PMOS
       LEVEL       1                1
           L   100.000000E-06   100.000000E-06
           W   100.000000E-06   100.000000E-06
         VTO       1               -1.5
          KP   500.000000E-06   400.000000E-06
       GAMMA       0                0
         PHI       .6               .6
      LAMBDA       .02              .05
          IS   10.000000E-15   10.000000E-15
        PBSW       .8               .8

 ****     SMALL SIGNAL BIAS SOLUTION       TEMPERATURE =   27.000 DEG C
********************************************************************************
 NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE     NODE   VOLTAGE
(   VS)   -1.6061  (  VCC)    5.0000  (  VD1)    2.8284  (  VEE)   -5.0000
(  VG1)    0.0000  ( VOUT)    2.8284

    VOLTAGE SOURCE CURRENTS
    NAME         CURRENT
    V_VCC       -2.000E-04
    V_VEE        2.000E-04
    V_VIN        0.000E+00

    TOTAL POWER DISSIPATION   2.00E-03  WATTS

 ****     OPERATING POINT INFORMATION      TEMPERATURE =   27.000 DEG C
********************************************************************************

**** MOSFETS
NAME            M_M1          M_M2          M_M4          M_M3
MODEL           Mbreakn       Mbreakn       Mbreakp       Mbreakp
ID              1.00E-04      1.00E-04     -1.00E-04     -1.00E-04
VGS             1.61E+00      1.61E+00     -2.17E+00     -2.17E+00
VDS             4.43E+00      4.43E+00     -2.17E+00     -2.17E+00
VBS             0.00E+00      0.00E+00      0.00E+00      0.00E+00
VTH             1.00E+00      1.00E+00     -1.50E+00     -1.50E+00
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2.

.out file

VDSAT	6.06E-01	6.06E-01	-6.72E-01	-6.72E-01
GM	3.30E-04	3.30E-04	2.98E-04	2.98E-04
GDS	1.84E-06	1.84E-06	4.51E-06	4.51E-06
GMB	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBD	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CBS	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGSOV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGDOV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGBOV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGS	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGD	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CGB	0.00E+00	0.00E+00	0.00E+00	0.00E+00

**** SMALL-SIGNAL CHARACTERISTICS

V(VOUT)/V_VIN = 5.160E+01

INPUT RESISTANCE AT V_VIN = 1.000E+20

OUTPUT RESISTANCE AT V(VOUT) = 1.580E+05

JOB CONCLUDED

TOTAL JOB TIME 1.57