University of California, Berkeley
EE142

Example Problem Set 1

1. (a) $I_{CC} = I_{C2} = 0.5mA$

$$g_m = \frac{1}{52\Omega}$$

$$\frac{\Delta V_o}{\Delta V_i} = -g_m R_L = -\frac{2000}{52} = -38.5$$

$$R_i = 2r_{\pi 1} = 2\frac{\beta_o}{g_m} = 200 \times 52 = 10.4K\Omega$$

Large signal $V_o = (I_{C2} - I_{C1})R_L$

$$= \alpha_F I_{EE} R_L \tanh\left(\frac{-V_{id}}{2V_T}\right)$$

$$\cong 2\tanh\left(\frac{-V_{id}}{52mV}\right)$$

(b) $$HD_3 = \frac{1}{48}\left(\frac{\hat{V}_i}{V_T}\right)^2$$

$$\hat{V}_i = 4mV \rightarrow HD_3 = \frac{1}{48}\left(\frac{4}{26}\right)^2 = 0.05\%$$

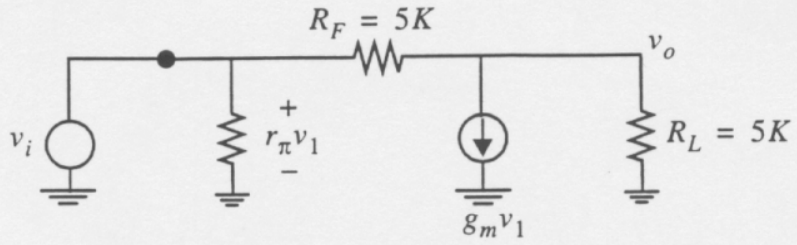
$$\hat{V}_i = 8mV \rightarrow HD_3 = 0.2\%$$

(c) $$Im_3 = 3HD_3 = \frac{1}{16}\left(\frac{\hat{V}_i}{V_T}\right)^2 = 0.02$$

$$\therefore \quad \hat{V}_i = 14.7mV$$

2. (a) Bias $I_C \cong \dfrac{V_{CC} - V_{BE}}{R_L} = \dfrac{5 - 0.8}{5K} = 0.84mA$

Small signal $\left[f = 1MHz \quad \dfrac{1}{\omega C} \cong 0 \quad \text{for} \quad C = 1\mu F\right]$



$$\frac{v_o - v_i}{R_F} + g_m v_i + \frac{v_o}{R_L} = 0$$

$$\therefore \quad v_o\left(\frac{1}{R_F} + \frac{1}{R_L}\right) = -v_i\left(g_m - \frac{1}{R_F}\right)$$

$$\therefore \quad \frac{v_o}{v_i} \cong -g_m(R_L \parallel R_F)$$

$$= -\frac{0.84}{26} \times 2500 = -81$$

$$R_i = r_\pi \parallel \frac{R_F}{1 + A_v}$$

$$= \frac{100 \times 26}{0.84} \parallel \frac{5000}{82}$$

$$= 3.1K \parallel 61\Omega$$

$$= 60\Omega$$

(b) $\hat{V}_i = 4\text{mV} \quad HD_3 = \dfrac{1}{24}\left(\dfrac{\hat{V}_i}{V_T}\right)^2 = \dfrac{1}{24}\left(\dfrac{4}{26}\right)^2 = 0.1\%$

$$HD_2 = \frac{1}{4}\frac{\hat{V}_i}{V_T} = 3.8\%$$

$\hat{V}_i = 8\text{mV} \quad HD_3 = 0.4\% \quad HD_2 = 7.7\%$

(c) $Im_3 = \dfrac{1}{8}\left(\dfrac{\hat{V}_i}{V_T}\right)^2$

$= 0.02$

for $\hat{V}_i = 10.4mV$

EECS 142 P.S.1 SOLN.


```
* Hw1,1: Differential amplifier

vcc     vcc 0 5
vee     vee 0 -5
iee     1 vee 1m

q1      vo+ vin 1 npn
q2      vo- 0 1 npn
r1      vcc vo+ 2k
r2      vcc vo- 2k

vin     vin 0 0 ac (1 0) sin (0 4m 1e6)

.model  npn npn bf=100 is=1e-16

.option post=2 nomod
.op
.tf     v(vo+,vo-) vin
.dc     vin -0.2 0.2 .01
.tran   .001u 4u
.four   1e6 v(vo+,vo-)
.alter

vin     vin 0 0 ac (1 0) sin (0 8m 1e6)
.end

**********************************************************************
* Output file
**********************************************************************

 ***** operating point status is all       simulation time is     0.

 +0:1       =-750.9857m 0:vcc     =   5.0000  0:vee     =  -5.0000
 +0:vin     =   0.      0:vo+     =   4.0099  0:vo-     =   4.0099

 **** bipolar junction transistors

 element  0:q1        0:q2
 model    0:npn       0:npn
  ib         4.9505u     4.9505u
  ic       495.0495u   495.0495u
  vbe      750.9857m   750.9857m
  vce        4.7609      4.7609
  vbc       -4.0099     -4.0099
  vs        -4.0099     -4.0099
  power      2.3606m     2.3606m
  betad    100.0000    100.0000
  gm        19.2687m    19.2687m
  rpi        5.1898k     5.1898k
  rx         0.          0.
  ro       4.009e+16   4.009e+16
  cpi        0.          0.
  cmu        0.          0.
  cbx        0.          0.
  ccs        0.          0.
  betaac   100.0000    100.0000
  ft       3.066e+12   3.066e+12

 ****     small-signal transfer characteristics

      v(vo+,vo-)/vin                          =  -38.5375
      input resistance at         vin         =   10.3795k
      output resistance at v(vo+,vo-)         =    4.0000k
```

```
 ******  fourier analysis                tnom=  25.000 temp=  25.000
 ******
fourier components of transient response v(vo+,vo-)
dc component =   9.113D-10
harmonic   frequency  fourier    normalized  phase     normalized
   no         (hz)    component  component   (deg)     phase (deg)

     1       1.0000x  153.9011m    1.0000   179.9992     0.
     2       2.0000x    1.8250n   11.8583n  124.9733   -55.0258
     3       3.0000x   80.4130u  522.4976u -179.0223  -359.0215
     4       4.0000x    1.8320n   11.9040n  159.9491   -20.0501
     5       5.0000x  719.5668n    4.6755u -133.2519  -313.2511
     6       6.0000x    1.8438n   11.9805n -165.0701  -345.0693
     7       7.0000x  278.7932n    1.8115u -103.2556  -283.2548
     8       8.0000x    1.8604n   12.0884n -130.0821  -310.0813
     9       9.0000x  150.0341n  974.8730n  -73.9375  -253.9366

    total harmonic distortion =    52.2523m  percent

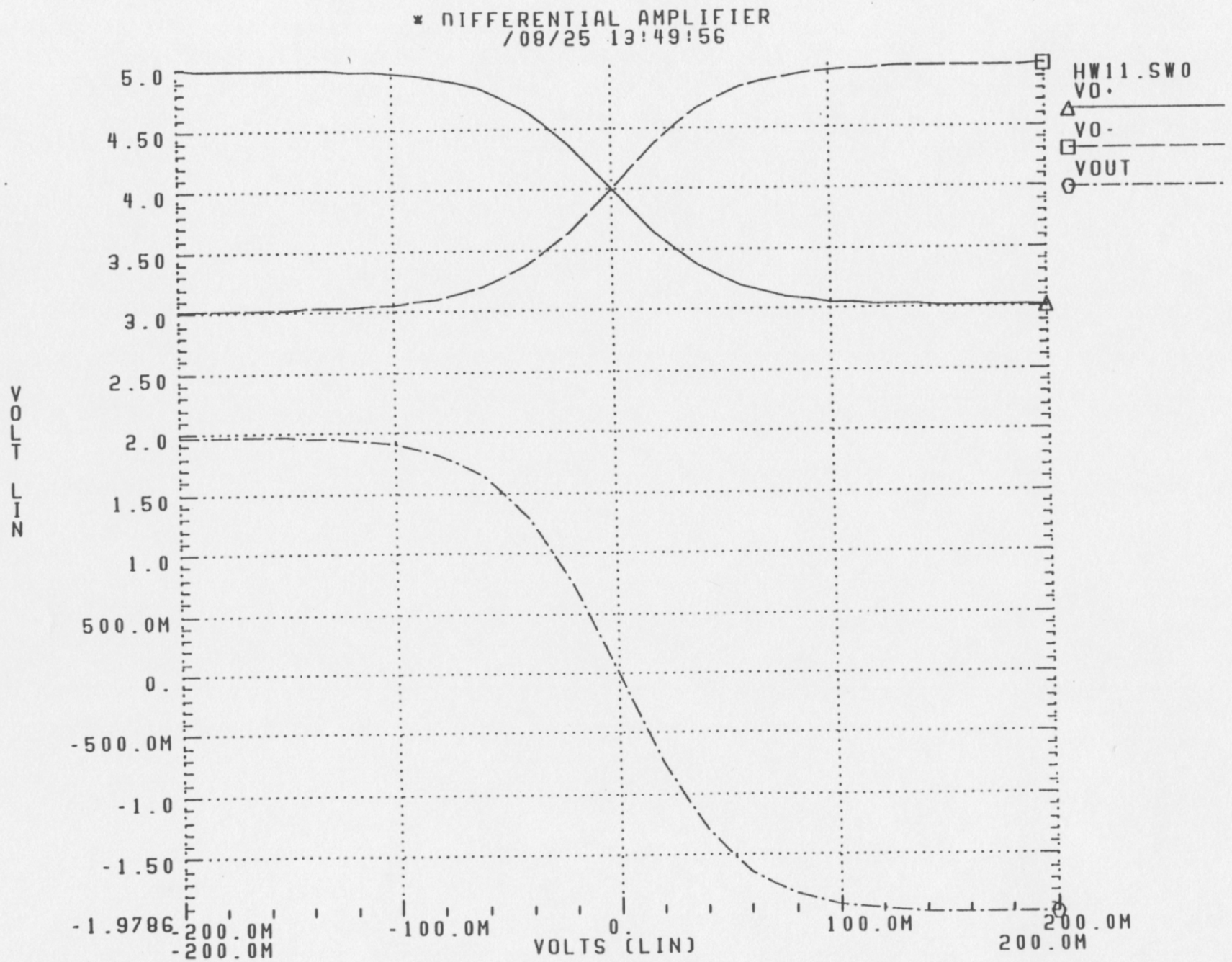
**********************************************************************
* Alter file
**********************************************************************

 vin    vin 0 0 ac (1 0) sin (0 8m 1e6)
 .end

 ******  fourier analysis                tnom=  25.000 temp=  25.000
 ******
 fourier components of transient response v(vo+,vo-)
 dc component =   1.879D-09
 harmonic   frequency  fourier    normalized  phase     normalized
    no         (hz)    component  component   (deg)     phase (deg)

      1       1.0000x  306.4153m    1.0000   179.9991     0.
      2       2.0000x    3.7632n   12.2812n  124.9756   -55.0236
      3       3.0000x  620.5145u    2.0251m -179.7488  -359.7479
      4       4.0000x    3.7777n   12.3285n  159.9537   -20.0455
      5       5.0000x    2.6965u    8.8002u -155.8679  -335.8671
      6       6.0000x    3.8019n   12.4078n -165.0633  -345.0625
      7       7.0000x  583.8513n    1.9054u -104.2633  -284.2625
      8       8.0000x    3.8362n   12.5195n -130.0730  -310.0721
      9       9.0000x  311.5393n    1.0167u  -74.3902  -254.3893

     total harmonic distortion =   202.5097m  percent
```


* DIFFERENTIAL AMPLIFIER
/08/25 13:49:56
HW11.SW0
VO+
VO-
VOUT
5.0
4.50
4.0
3.50
3.0
2.50
2.0
1.50
1.0
500.0M
0.
-500.0M
-1.0
-1.50
-1.9786
VOLT LIN
-200.0M
-100.0M
0.
100.0M
200.0M
-200.0M
200.0M
VOLTS (LIN)

```
* Hw1, problem 2

vcc     vcc 0 5

r1      vcc vout 5k
r2      vout vin 5k

q1      vout vin 0 npn

vin     vin 0 764.2789m sin(764.2789m 4m 1e6)

* Note: the capacitor can be ignored at f=1Mhz

.model  npn npn bf=100 is=1e-16

.option post=2 nomod
.op
.tf     v(vout) vin
.tran   .001u 4u
.four   1e6 v(vout)
.alter

vin     vin 0 764.2789m sin(764.2789m 8m 1e6)

.end

**********************************************************************
* Output file
**********************************************************************

 ***** operating point status is all       simulation time is     0.

 +0:vcc     =   5.0000  0:vin     = 764.2789m 0:vout    = 805.8072m

 **** bipolar junction transistors

 element  0:q1
 model    0:npn
  ib         8.3053u
  ic       830.5329u
  vbe      764.2789m
  vce      805.8072m
  vbc      -41.5283m
  vs      -805.8072m
  power    675.5970u
  betad    100.0000
  gm        32.3267m
  rpi        3.0934k
  rx         0.
  ro       1.293e+15
  cpi        0.
  cmu        0.
  cbx        0.
  ccs        0.
  betaac   100.0000
  ft       5.145e+12

 ****     small-signal transfer characteristics

      v(vout)/vin                              =  -80.3168
      input resistance at          vin         =   60.2895
      output resistance at v(vout)             =    2.5000k

 ******  fourier analysis                 tnom=  25.000 temp=  25.000
******
fourier components of transient response v(vout)
dc component =   7.932D-01
harmonic   frequency  fourier    normalized  phase     normalized
   no         (hz)    component  component   (deg)     phase (deg)

     1       1.0000x  322.2146m    1.0000   179.9992     0.
     2       2.0000x   12.6038m   39.1163m   90.0014   -89.9978
     3       3.0000x  320.7861u  995.5665u -514.9512m -180.5141
     4       4.0000x    5.4180u   16.8147u  -99.4745  -279.4737
     5       5.0000x    1.3909u    4.3165u -131.9410  -311.9402
     6       6.0000x  352.2095n    1.0931u  175.4571    -4.5420
     7       7.0000x  556.7797n    1.7280u -103.0223  -283.0215
     8       8.0000x  165.9884n  515.1487n -145.0923  -325.0914
     9       9.0000x  302.3556n  938.3671n  -73.4462  -253.4454

    total harmonic distortion =     3.9129   percent


**********************************************************************
* Alter file
**********************************************************************

 vin    vin 0 764.2789m sin(764.2789m 8m 1e6)

  ******  fourier analysis                 tnom=  25.000 temp=  25.000
 ******
 fourier components of transient response v(vout)
 dc component =   7.620D-01
 harmonic   frequency  fourier    normalized  phase     normalized
    no         (hz)    component  component   (deg)     phase (deg)

      1       1.0000x  637.0103m    1.0000   179.9991     0.
      2       2.0000x   38.5415m   60.5038m   89.9999   -89.9992
      3       3.0000x    7.8376m   12.3038m -179.9474  -359.9465
      4       4.0000x    8.2719m   12.9855m   90.0310   -89.9682
      5       5.0000x    6.1863m    9.7115m  -15.9811m -180.0151
      6       6.0000x    4.1485m    6.5125m  -90.0296  -270.0287
      7       7.0000x    2.4212m    3.8008m  179.9895    -9.6436m
      8       8.0000x    1.1068m    1.7375m   89.9373   -90.0619
      9       9.0000x  228.1506u  358.1585u -543.1837m -180.5423

     total harmonic distortion =     6.4304   percent
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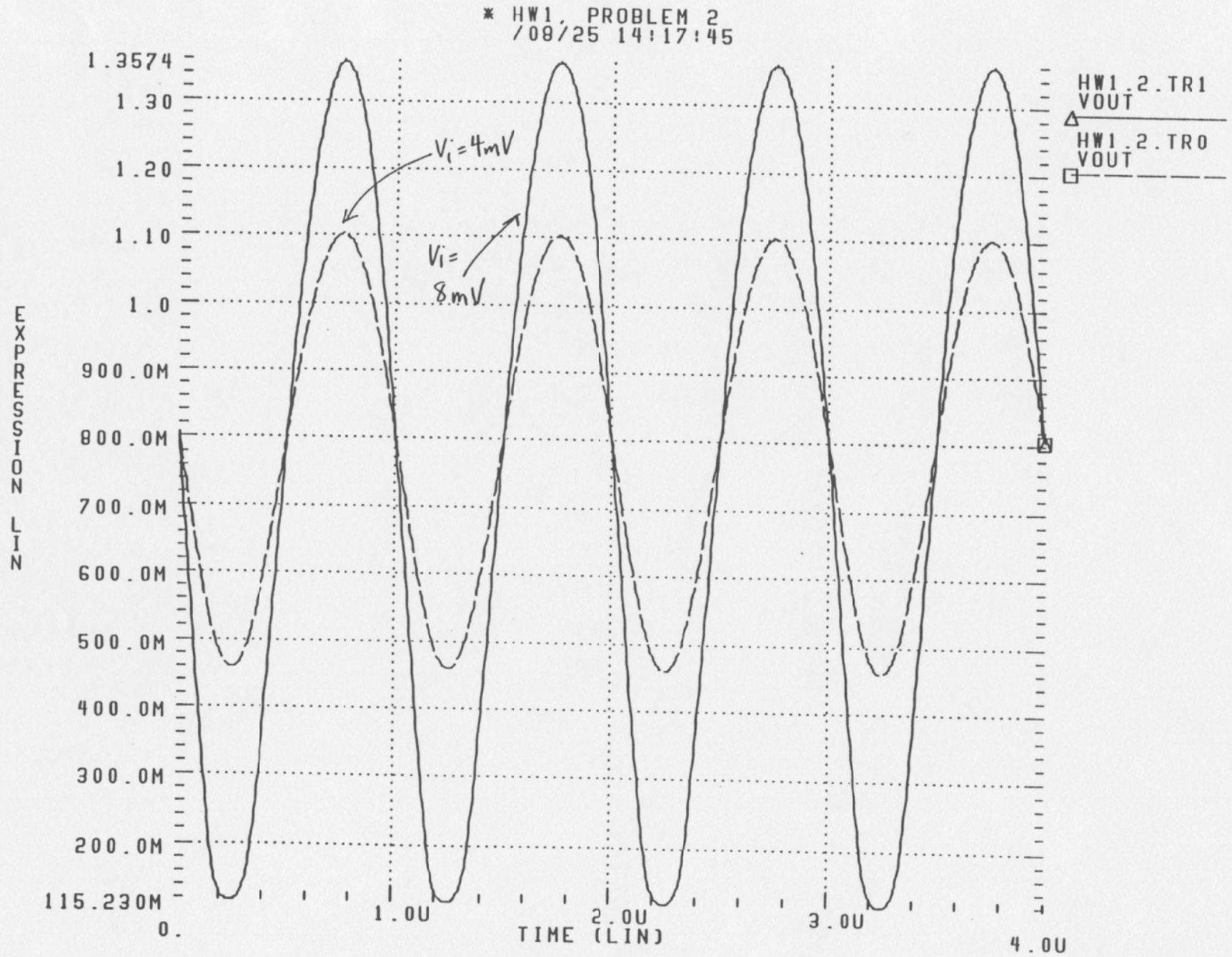
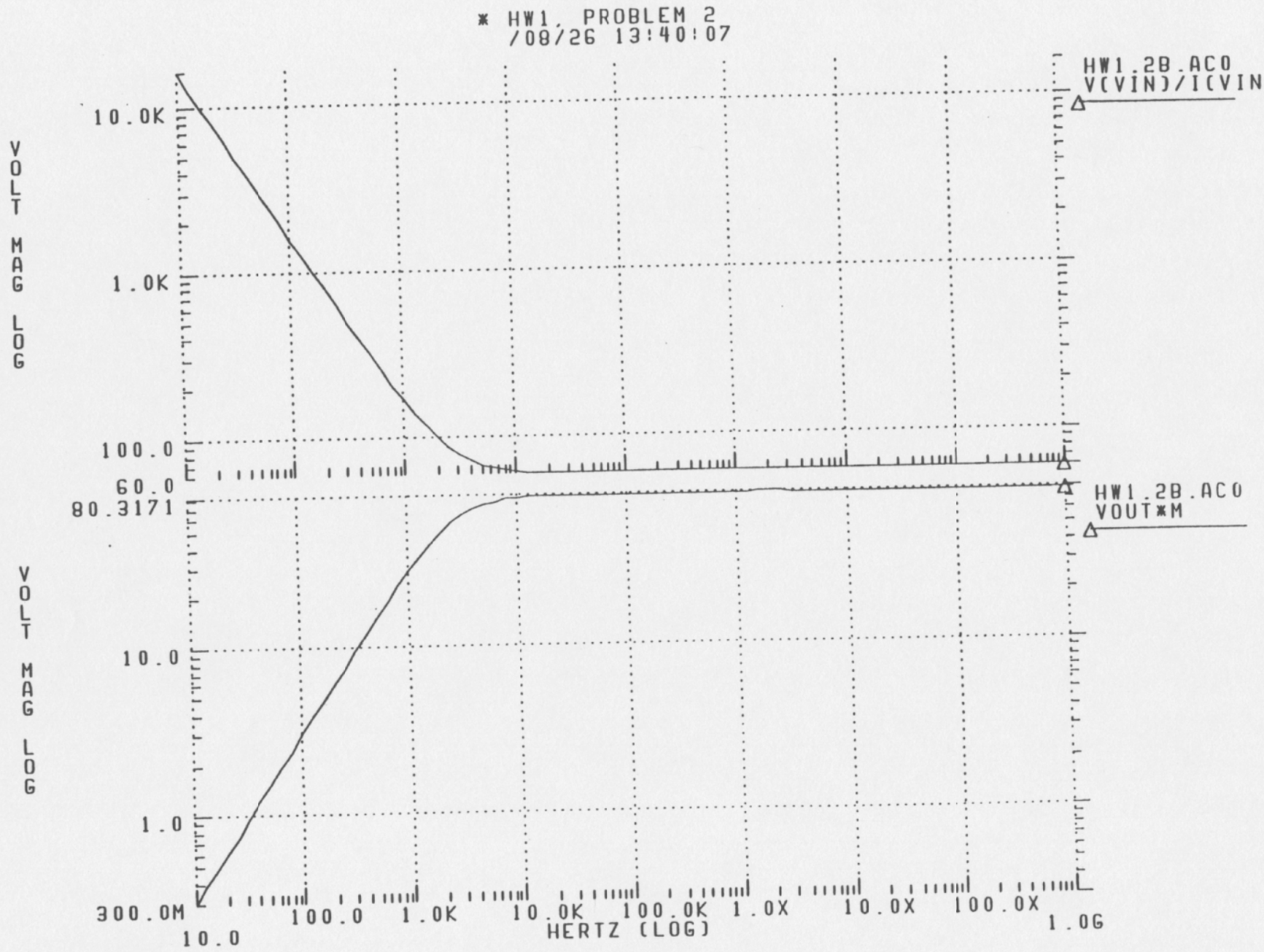

* HW1, PROBLEM 2
/08/25 14:17:45
1.3574
1.30
1.20
1.10
1.0
900.0M
800.0M
700.0M
600.0M
500.0M
400.0M
300.0M
200.0M
115.230M
0.
EXPRESSION LIN
V_i=4mV
V_i=
8mV
HW1.2.TR1
VOUT
HW1.2.TR0
VOUT
1.0U
2.0U
3.0U
4.0U
TIME (LIN)


* HW1, PROBLEM 2
/08/26 13:40:07
HW1.2B.AC0
V(VIN)/I(VIN
HW1.2B.AC0
VOUT*M
VOLT MAG LOG
10.0K
1.0K
100.0
60.0
80.3171
VOLT MAG LOG
10.0
1.0
300.0M
10.0
100.0
1.0K
10.0K
100.0K
1.0X
10.0X
100.0X
1.0G
HERTZ (LOG)