

## CHAPTER 7

### 7.1

(a) Transistor parameters are

$$r_{\pi} = \frac{\beta_o}{g_m} = 200 \times 52 = 10.4 \text{ k}\Omega$$

$$\tau_T = \frac{1}{2\pi f_T} = 318 \text{ ps}$$

$$C_{\pi} + C_{\mu} = g_m \tau_T = \frac{1}{52} \times 318 = 6.12 \text{ pF}$$

$$\therefore C_{\pi} = 6.1 - 0.3 = 5.8 \text{ pF}$$

$$C_M = (1 + g_m R_L) C_{\mu} \\ = \left(1 + \frac{3000}{52}\right) \times 0.3 = 17.6 \text{ pF}$$

In (7.12) and (7.9)

$$f_{-3dB} = \frac{1}{2\pi} \frac{5000 + 300 + 10400}{(5000 + 300) \times 10400} \frac{10^{12}}{5.8 + 17.6} \\ = 1.94 \text{ MHz}$$

(b) From (7.27)

$$P_2 = -\left(\frac{1}{R_L C_{\mu}} + \frac{1}{R C_{\pi}} + \frac{1}{R_L C_{\pi}} + \omega_T\right)$$

$$R = (R_S + r_b) \parallel r_{\pi}$$

$$= 5300 \parallel 10400 = 3511 \Omega$$

$$\therefore P_2 = -\left(\frac{10^{12}}{3000 \times 0.3} + \frac{10^{12}}{3511 \times 5.8} + \frac{10^{12}}{3000 \times 5.8}\right.$$

$$\left. + 2\pi \times 500 \times 10^6\right)$$

$$= -(11.1 + 0.49 + 0.57 + 31.4) \times 10^8 \text{ rad/sec}$$

$$= -43.6 \times 10^8 \text{ rad/sec}$$

$$= -693 \text{ MHz}$$

COMMON EMITTER GAIN STAGE

VCC 1 0 5V  
 RL 1 2 3K  
 Q1 2 3 0 NPN  
 RS 4 3 5K  
 VI 4 0 0.7696 AC  
 .TF V(2) VI  
 .PLOT AC VDB(2)  
 .PLOT AC VP(2)  
 .AC DEC 10 100K 1GIG  
 .MODEL NPN NPN IS=1E-16A BF=200  
 + RB=300 CJC=0.3PF CJS=0 TP=302PS  
 \* ASSUME CJE SMALL COMPARED TO CB  
 .OPTIONS NOPAGE NOMOD  
 .WIDTH OUT=80  
 .OPTIONS SPICE  
 .OP  
 .END

\*\*\*\*\* OPERATING POINT INFORMATION TNOM= 27.000 TEMP= 27.000

+0:1 = 5.000E+00 0:2 = 3.497E+00 0:3 = 7.571E-01  
 +0:4 = 7.696E-01

\*\*\*\* BIPOLAR JUNCTION TRANSISTORS

ELEMENT 0:Q1  
 MODEL 0:NPN  
 IB 2.504E-06  
 IC 5.009E-04  
 VBE 7.571E-01  
 VCE 3.497E+00  
 VBC -2.740E+00  
 VS -3.497E+00  
 POWER 1.754E-03  
 BETAD 2.000E+02  
 GM 1.937E-02  
 RPI 1.032E+04  
 RI 3.000E+02  
 RO 2.741E+16  
 CPI 5.849E-12  
 CMU 1.806E-13  
 CBX 0.  
 CCS 0.  
 BETAAC 2.000E+02  
 FT 5.112E+08

\*\*\*\* SMALL-SIGNAL TRANSFER CHARACTERISTICS

V(2)/VI = -3.839E+01  
 INPUT RESISTANCE AT VI = 1.562E+04  
 OUTPUT RESISTANCE AT V(2) = 3.000E+03

\*\*\*\*\* AC ANALYSIS

TNOM= 27.000 TEMP= 27.000

FREQ	VDB(2)					
1.000E+05	3.16E+01	-4.000E+01	-2.000E+01	0.	2.000E+01	4.000E+01
1.258E+05	3.16E+01					
1.584E+05	3.16E+01					
1.995E+05	3.16E+01					
2.511E+05	3.16E+01					
3.162E+05	3.16E+01					
3.981E+05	3.15E+01					
5.011E+05	3.15E+01					
6.309E+05	3.14E+01					
7.943E+05	3.13E+01					
1.000E+06	3.11E+01					
1.258E+06	3.08E+01					
1.584E+06	3.04E+01					
1.995E+06	2.99E+01					
2.511E+06	2.90E+01					
3.162E+06	2.80E+01					
3.981E+06	2.67E+01					
5.011E+06	2.52E+01					
6.309E+06	2.36E+01					
7.943E+06	2.19E+01					
1.000E+07	2.01E+01					
1.258E+07	1.82E+01					
1.584E+07	1.62E+01					
1.995E+07	1.43E+01					
2.511E+07	1.23E+01					
3.162E+07	1.03E+01					
3.981E+07	8.39E+00					
5.011E+07	6.39E+00					
6.309E+07	4.38E+00					
7.943E+07	2.37E+00					
1.000E+08	3.56E-01					
1.258E+08	-1.67E+00					
1.584E+08	-3.73E+00					
1.995E+08	-5.82E+00					
2.511E+08	-7.95E+00					
3.162E+08	-1.01E+01					
3.981E+08	-1.24E+01					
5.011E+08	-1.49E+01					
6.309E+08	-1.75E+01					
7.943E+08	-2.03E+01					
1.000E+09	-2.34E+01					

FREQ	VP(2)					
1.000E+05	1.77E+02	5.000E+01	1.000E+02	1.500E+02	2.000E+02	
1.258E+05	1.77E+02					
1.584E+05	1.76E+02					
1.995E+05	1.75E+02					
2.511E+05	1.74E+02					
3.162E+05	1.73E+02					
3.981E+05	1.71E+02					
5.011E+05	1.69E+02					
6.309E+05	1.67E+02					
7.943E+05	1.63E+02					
1.000E+06	1.59E+02					
1.258E+06	1.55E+02					
1.584E+06	1.49E+02					
1.995E+06	1.43E+02					
2.511E+06	1.37E+02					
3.162E+06	1.30E+02					
3.981E+06	1.24E+02					
5.011E+06	1.18E+02					
6.309E+06	1.13E+02					
7.943E+06	1.08E+02					
1.000E+07	1.04E+02					
1.258E+07	1.01E+02					
1.584E+07	9.86E+01					
1.995E+07	9.63E+01					
2.511E+07	9.44E+01					
3.162E+07	9.26E+01					
3.981E+07	9.10E+01					
5.011E+07	8.95E+01					
6.309E+07	8.79E+01					
7.943E+07	8.62E+01					
1.000E+08	8.44E+01					
1.258E+08	8.22E+01					
1.584E+08	7.97E+01					
1.995E+08	7.66E+01					
2.511E+08	7.30E+01					
3.162E+08	6.86E+01					
3.981E+08	6.35E+01					
5.011E+08	5.76E+01					
6.309E+08	5.10E+01					
7.943E+08	4.39E+01					
1.000E+09	3.66E+01					

$$g_m = \sqrt{2k_n' \frac{W}{L} I_D} = \sqrt{2 \times 60 \times 10^{-6} \times \frac{100}{2 \times 2 \times 0.2} \times 500 \times 10^{-6}}$$

$$= 1.9 \times 10^{-3} \text{ A/V}$$

$$A_v = -g_m R_L = -1.9 \times 10^{-3} \times 5 \times 10^3 = -9.5$$

$$C_{gs} = \frac{2}{3} W L_{\text{eff}} C_{ox} + W L_d C_{ox}$$

$$= \frac{2}{3} 100 \times 1.6 \times 0.7 + 100 \times 0.2 \times 0.7$$

$$= 89 \text{ fF}$$

$$C_{gd} = W L_d C_{ox} = 100 \times 0.2 \times 0.7 = 14 \text{ fF}$$

(a) Use the Miller effect.

$$|P_1| = \frac{1}{R_s [C_{gs} + C_{gd}(1 - A_v)]}$$

$$= \frac{1}{10k [89 + 14(1 + 9.5)] \times 10^{-15}}$$

$$= \frac{1}{2.4 \times 10^{-9}} = 4.2 \times 10^8 \text{ rad/s}$$

$$f_{-3dB} = \frac{|P_1|}{2\pi} = 67 \text{ MHz}$$

(b) Do not use the Miller effect to calculate the second pole.

From Eq. (7.26),

$$|P_2| = \frac{1}{|A_v| R_L R_s C_{gd} C_{gs}}$$

$$= \frac{1}{4.2 \times 10^8 \times 5k \times 10k \times 14 \text{ f} \times 89 \text{ f}}$$

$$= 3.8 \times 10^{10} \text{ rad/s}$$

It is equivalent to 6.1 GHz.

## COMMON SOURCE AMPLIFIER

```

VDD 1 0 5
VI 2 0 DC 1.216 AC 1
RS 2 3 10K
RL 1 4 5K
M1 4 3 0 0 CMOSN W=100U L=2U
* COX'=0.7FF/UM**2=BOX/TOX => TOX=500 ANGSTROMS
.MODEL CMOSN NMOS LKVEL=1 LAMBDA=0 VTO=0.7 KP=60U LD=0.2U TOX=500E-10
.OPTIONS NOMOD
.AC DEC 10 1MEG 10G
.PLOT AC VM(4)
.WIDTH OUT=80
.OPTIONS SPICE
.END

```

\*\*\*\*\* OPERATING POINT INFORMATION TNUM= 27.000 TEMP= 27.000

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+0:1 = 5.000E+00 0:2 = 1.216E+00 0:3 = 1.216E+00
+0:4 = 2.503E+00

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\*\*\*\* MOSFETS

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SUBCIR 0:M1
ELEMENT 0:M1
MODEL 0:CMOSN
ID 4.992E-04
IBS 0.
IRD -2.504E-14
VGS 1.216E+00
VDS 2.503E+00
VBS 0.
VTH 7.000E-01
VDSAT 5.160E-01
BETA 3.750E-03
GAM KFF 0.
GM 1.935E-03
GDS 0.
GMS 0.
COTOT 1.418E-14
COFOT 1.050E-13
CSTOT 8.748E-14
CBTOT 3.349E-15
CGS 8.748E-14
CGD 1.418E-14

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\*\*\*\*\* AC ANALYSIS TNUM= 27.000 TEMP= 27.000

FREQ	VM(4)	1.000E-02	1.000E-01	1.000E+00	9.999E+00	9.999E+01
1.000E+06	9.67E+00					
1.258E+06	9.67E+00	+	+	+	+	A
1.584E+06	9.67E+00	+	+	+	+	A
1.995E+06	9.67E+00	+	+	+	+	A
2.511E+06	9.66E+00	+	+	+	+	A
3.162E+06	9.66E+00	+	+	+	+	A
3.981E+06	9.65E+00	+	+	+	+	A
5.011E+06	9.64E+00	+	+	+	+	A
6.309E+06	9.62E+00	+	+	+	+	A
7.943E+06	9.60E+00	+	+	+	+	A
1.000E+07	9.56E+00					
1.258E+07	9.49E+00	+	+	+	+	A
1.584E+07	9.39E+00	+	+	+	+	A
1.995E+07	9.24E+00	+	+	+	+	A
2.511E+07	9.01E+00	+	+	+	+	A
3.162E+07	8.68E+00	+	+	+	+	A
3.981E+07	8.23E+00	+	+	+	+	A
5.011E+07	7.64E+00	+	+	+	+	A
6.309E+07	6.91E+00	+	+	+	+	A
7.943E+07	6.09E+00	+	+	+	+	A
1.000E+08	5.24E+00					
1.258E+08	4.41E+00	+	+	+	+	A
1.584E+08	3.64E+00	+	+	+	+	A
1.995E+08	2.97E+00	+	+	+	+	A
2.511E+08	2.40E+00	+	+	+	+	A
3.162E+08	1.93E+00	+	+	+	+	A
3.981E+08	1.54E+00	+	+	+	+	A
5.011E+08	1.23E+00	+	+	+	+	A
6.309E+08	9.79E-01	+	+	+	+	A
7.943E+08	7.77E-01	+	+	+	+	A
1.000E+09	6.15E-01					
1.258E+09	4.86E-01	+	+	+	+	A
1.584E+09	3.82E-01	+	+	+	+	A
1.995E+09	2.98E-01	+	+	+	+	A
2.511E+09	2.31E-01	+	+	+	+	A
3.162E+09	1.77E-01	+	+	+	+	A
3.981E+09	1.33E-01	+	+	+	+	A
5.011E+09	9.87E-02	+	+	+	+	A
6.309E+09	7.16E-02	+	+	+	+	A
7.943E+09	5.09E-02	+	+	+	+	A
1.000E+10	3.58E-02					

7.8

$$\frac{v_o}{v_i} = \frac{g_m R_E + \frac{R_E}{r_\pi}}{1 + g_m R_E + \frac{R_b + R_E}{r_\pi}} \frac{1 - \frac{s}{z_1}}{1 - \frac{s}{p_1}}$$

$$= \frac{\frac{0.3 \times 4000 + \frac{4000}{50} \cdot \frac{0.3}{26}}{1 + \frac{0.3 \times 4000 + \frac{4450}{50} \cdot \frac{0.3}{26}}}{1 - \frac{j\omega}{z_1}} \frac{1 - \frac{j\omega}{z_1}}{1 - \frac{j\omega}{p_1}}$$

$$= 0.977 \frac{1 - j \frac{\omega}{z_1}}{1 - j \frac{\omega}{p_1}}$$

$$z_1 = -\frac{g_m}{C_\pi} = -\omega_T = -2\pi \times 4 \times 10^6$$

$$= -25.1 \times 10^6 \text{ rad/sec}$$

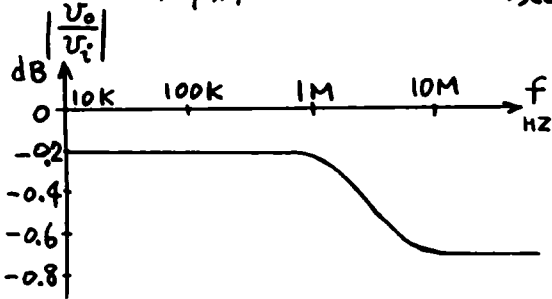
$$p_1 = -\frac{1}{C_\pi R_1}$$

$$R_1 = r_\pi \parallel \frac{R_b + R_E}{1 + g_m R_E} = \frac{50 \times 26}{0.3} \parallel \frac{450 + 4000}{1 + \frac{0.3 \times 4000}{26}}$$

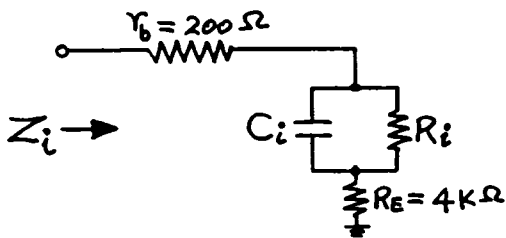
$$= 4333 \parallel 94.4 = 92.4 \Omega$$

$$C_\pi = \frac{g_m}{\omega_T} = \frac{0.3}{26} \frac{1}{2\pi \times 4 \times 10^6} = 459 \text{ pF}$$

$$\therefore p_1 = -\frac{10^{12}}{459 \times 92.4} = -23.6 \times 10^6 \text{ rad/sec}$$



7.9

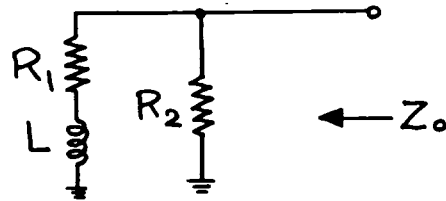


$$C_i = \frac{C_\pi}{1 + g_m R_E} = \frac{459}{1 + \frac{0.3 \times 4000}{26}} = 9.73 \text{ pF}$$

$$R_i = (1 + g_m R_E) r_\pi = \left(1 + \frac{0.3 \times 4000}{26}\right) \times \frac{50 \times 26}{0.3}$$

$$= 204 \text{ k}\Omega$$

$$Z_i = 4.2 \text{ k}\Omega + 204 \text{ k}\Omega \parallel \frac{1}{j\omega C_i}$$

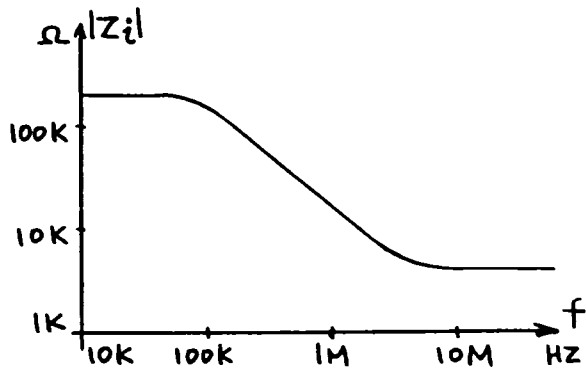
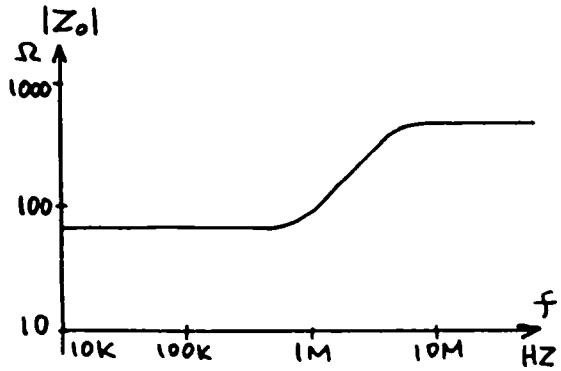


$$R_1 = \frac{1}{g_m} + \frac{R_b}{\beta_o} = \frac{26}{0.3} + \frac{450}{50} = 95.7 \Omega$$

$$R_2 = R_b = 450 \Omega$$

$$L = C_\pi r_\pi \frac{R_b}{\beta_o} = 459 \times \frac{50 \times 26}{0.3} \times \frac{450}{50} \times 10^{-12}$$

$$= 17.9 \mu\text{H}$$



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PNP EMITTER FOLLOWER, RESISTIVE LOAD
* DC VO=0V, 300UA*4K=1.2V=VCC
VCC 1 0 1.2V
VEE 2 0 -1.2V
RE 1 5 4K
Q1 2 4 5 PNP
RS 3 4 250
RLOAD 5 0 1K
VBIAS 3 6 -0.745V AC
VPULSE 6 0 PULSE 0V 1MV 1NS 0NS 0NS 100NS
.TRAN 0.25MS 10NS
.PLOT TRAN V(5)
.MODEL PNP PNP IS=1E-16A BF=50
+ RB=200 CJE=0 CJC=0 CJS=0 TF=39.8NS
.OPTIONS NOPAGE NOMOD
.WIDTH OUT=80
.OPTIONS SPICE
.OP
.END

```

```

***** OPERATING POINT INFORMATION          TNOM= 27.000 TEMP= 27.000

+0:1      = 1.200E+00 0:2      = -1.200E+00 0:3      = -7.450E-01
+0:4      = -7.435E-01 0:5      = 1.819E-04 0:6      = 0.

```

\*\*\*\* BIPOLAR JUNCTION TRANSISTORS

```

ELEMENT 0:Q1
MODEL 0:PNP
IB -5.878E-06
IC -2.939E-04
VBE -7.437E-01
VCE -1.200E+00
VBC 4.565E-01
VS 7.424E-01
POWER 3.571E-04
BETAD 5.000E+01
GM 1.137E-02
RPI 4.400E+03
RX 2.000E+02
RO 4.576E+15
CPI 4.522E-10
CMU 0.
CBX 0.
CCS 0.
BETAAC 5.000E+01
FT 3.998E+06

```

\*\*\*\*\* TRANSIENT ANALYSIS TNOM= 27.000 TEMP= 27.000

TIME	V(5)
0.	1.82E-04
2.500E-10	1.82E-04
5.000E-10	1.82E-04
7.500E-10	1.82E-04
1.000E-09	1.82E-04
1.250E-09	8.23E-04
1.500E-09	8.24E-04
1.750E-09	8.25E-04
2.000E-09	9.76E-04
2.250E-09	8.27E-04
2.500E-09	8.28E-04
2.750E-09	8.29E-04
3.000E-09	8.31E-04
3.250E-09	8.32E-04
3.500E-09	8.33E-04
3.750E-09	8.34E-04
4.000E-09	8.35E-04
4.250E-09	8.36E-04
4.500E-09	8.37E-04
4.750E-09	8.38E-04
5.000E-09	8.39E-04
5.250E-09	8.40E-04
5.500E-09	8.42E-04
5.750E-09	8.43E-04
6.000E-09	8.44E-04
6.250E-09	8.45E-04
6.500E-09	8.46E-04
6.750E-09	8.47E-04
7.000E-09	8.48E-04
7.250E-09	8.49E-04
7.500E-09	8.50E-04
7.750E-09	8.51E-04

\*\*\*\* PNP EMITTER FOLLOWER, CAPACITIVE LOAD

```

VCC 1 0 1.2V
VEE 2 0 -1.2V
IER 1 5 300UA
Q1 2 4 5 PNP
RS 3 4 250
CLOAD 5 0 400PF
VBIAS 3 6 -0.745V AC
VPULSE 6 0 PULSE 0V 1MV 1NS 0NS 0NS 1300NS
.TRAN 20NS 800NS

```

```

.PLOT TRAN V(5)
.MODEL PNP PNP IS=1E-16A BF=50
+ RB=200 CJE=0 CJC=0 CJS=0 TF=39.8NS
.OPTIONS NOPAGE NOMOD
.WIDTH OUT=80
.OPTIONS SPICE
.OP
.END

```

\*\*\*\* BIPOLAR JUNCTION TRANSISTORS

```

ELEMENT 0:Q1
MODEL 0:PNP
IB -5.882E-06
IC -2.941E-04
VBE -7.437E-01
VCE -1.200E+00
VBC 4.565E-01
VS 7.424E-01
POWER 3.574E-04
BETAD 5.000E+01
GM 1.137E-02
RPI 4.396E+03
RX 2.000E+02
RO 4.576E+15
CPI 4.526E-10
CMU 0.
CBX 0.
CCS 0.
BETAAC 5.000E+01
FT 3.998E+06

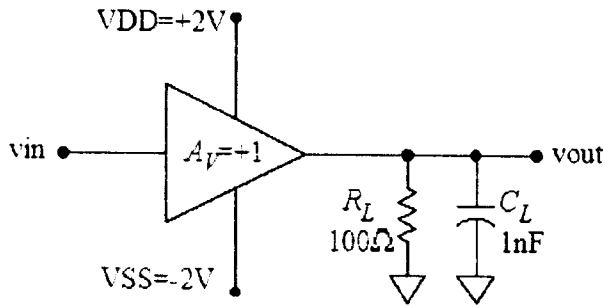
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\*\*\*\*\* TRANSIENT ANALYSIS TNOM= 27.000 TEMP= 27.000

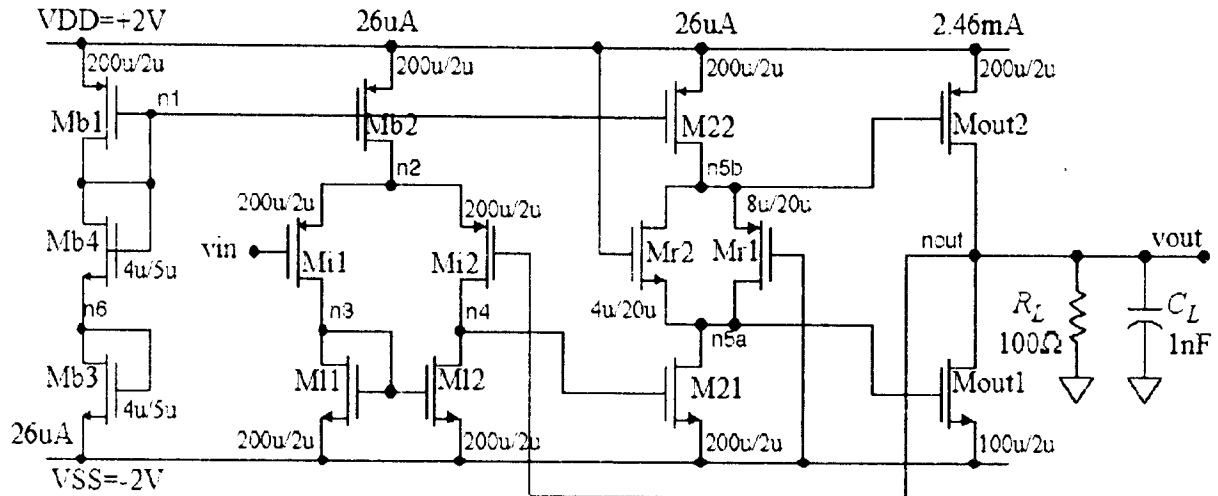
TIME	V(5)
0.	2.03E-04
2.000E-08	2.59E-04
4.000E-08	1.94E-04
6.000E-08	5.42E-04
8.000E-08	6.95E-04
1.000E-07	8.44E-04
1.200E-07	9.81E-04
1.400E-07	1.10E-03
1.600E-07	1.21E-03
1.800E-07	1.29E-03
2.000E-07	1.35E-03
2.200E-07	1.39E-03
2.400E-07	1.42E-03
2.600E-07	1.43E-03
2.800E-07	1.42E-03
3.000E-07	1.41E-03
3.200E-07	1.39E-03
3.400E-07	1.36E-03
3.600E-07	1.33E-03
3.800E-07	1.30E-03
4.000E-07	1.27E-03
4.200E-07	1.24E-03
4.400E-07	1.22E-03
4.600E-07	1.20E-03
4.800E-07	1.18E-03
5.000E-07	1.17E-03
5.200E-07	1.16E-03
5.400E-07	1.16E-03
5.600E-07	1.16E-03
5.800E-07	1.16E-03
6.000E-07	1.16E-03
6.200E-07	1.17E-03
6.400E-07	1.17E-03
6.600E-07	1.19E-03
6.800E-07	1.19E-03
7.000E-07	1.19E-03
7.200E-07	1.20E-03
7.400E-07	1.20E-03
7.600E-07	1.21E-03
7.800E-07	1.21E-03
8.000E-07	1.21E-03

\*\*\*\*\* CAPACITIVE LOAD RESULTS IN SOME PEAKING [V(5) JUMPS BY > 1MV]

# Problem 5 - Design Prob. #1



Output swing	-1.25V, 1.06V
SR	> 10V/usec
DC gain	= 1
efficiency	= 30.6%
score	40

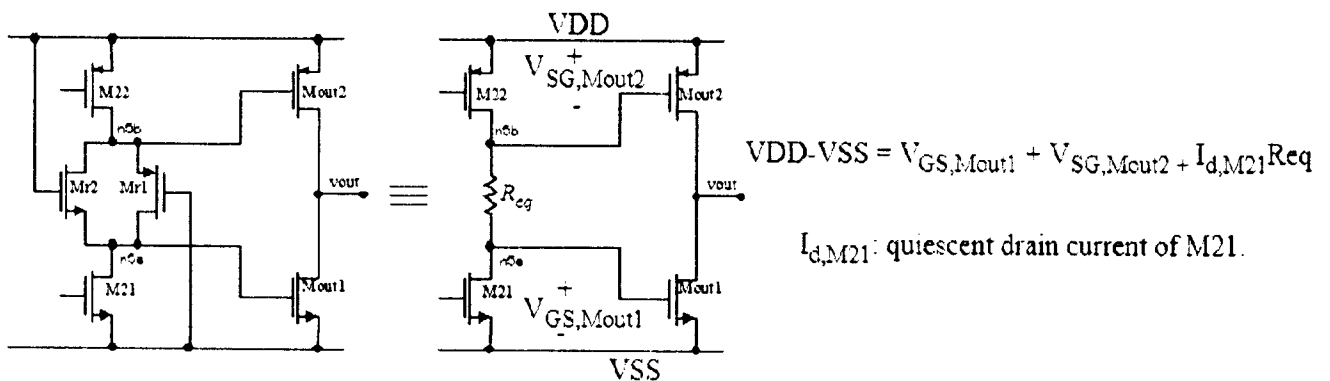


A three stage amplifier connected in unity gain configuration is used as the output buffer. The first two stages are class-A whereas the last stage is class-AB.

1nF load capacitance makes the pole present at node nout the dominant pole. Therefore, there is no need to apply additional compensation to the three stage amplifier.

DC gain of the amplifier in unity gain configuration =  $A_v / (1 + A_v)$   
 where  $A_v \propto g_m r_{ds}$

Output impedance of the unity gain buffer =  $r_{ds} / (1 + A_v)$ .



Mr1 and Mr2 act as a linear resistor, allowing a voltage drop between n5a and n5b. The net result is reduced quiescent current at the output stage.

```

*output buffer
.option brief
.options
+ post
+ ingold=2
+ scale=1e-6
+ accurate
+ delmax=0.5n
+ method=gear lvltim=2
+ probe
*

vdd dd 0 dc 2v
vss ss 0 dc -2v
*vin in 0 dc 0v
vin in 0 sin (0 1.5 100k 0)
*vin in 0 pulse (-1 1 2u 2n 2n 1u 2u)

mb1 n1 n1 dd dd cmosp l=2u w=200u
mb2 n2 n1 dd dd cmosp l=2u w=200u
mb3 n6 n6 ss ss cmosn l=5u w=4u
mb4 n1 n1 n6 ss cmosn l=5u w=4u
mi1 n3 in n2 n2 cmosp l=2u w=200u
mi2 n4 nout n2 n2 cmosp l=2u w=200u
ml1 n3 n3 ss ss cmosn l=2u w=200u
ml2 n4 n3 ss ss cmosn l=2u w=200u
m21 n5a n4 ss ss cmosn l=2u w=200u
m22 n5b n1 dd dd cmosp l=2u w=200u
mr1 n5a ss n5b dd cmosp l=20u w=8u
mr2 n5b dd n5a ss cmosn l=20u w=4u
mout1 nout n5a ss ss cmosn l=2u w=100u
mout2 nout n5b dd dd cmosp l=2u w=200u
r1 nout 0 100
cl nout ss 1nF
*.dc vin -2 2 1m
.meas tran current_vdd avg i(vdd) from=0 to=50u
.meas tran power_vdd param='4*current_vdd'
} calculates the average
  current drawn from VDD.
  and power

.tran 1u 50u
.model cmosn nmos kp=110u vto=0.7 lambda=0.01 gamma=0.4 phi=0.7
.model cmosp pmos kp=50u vto=-0.7 lambda=0.01 gamma=0.7 phi=0.8
.probe v(in) v(n1) v(n2) v(n3) v(n4) v(n5) v(nout) v(n5a) v(n5b) i(vdd) i(vss)
.op
.end

```

\*\*\*\*\* operating point information tnom= 25.000 temp= 25.000

\*\*\*\*\*

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

node	=voltage	node	=voltage	node	=voltage
+0:dd	= 2.000e+00	0:in	= 0.	0:n1	= 1.197e+00
+0:n2	= 7.723e-01	0:n3	=-1.250e+00	0:n4	=-1.230e+00
+0:n5a	=-3.641e-01	0:n5b	= 3.185e-01	0:n6	=-5.283e-01
+0:nout	=-1.441e-05	0:ss	=-2.000e+00		

\*\*\*\* voltage sources

subckt

element	0:vdd	0:vss	0:vin
volts	2.000e+00	-2.000e+00	0.
current	-2.537e-03	2.537e-03	0.
power	5.073e-03	5.074e-03	0.

total voltage source power dissipation= 1.015e-02 watts

\*\*\*\* resistors

subckt

element	0:r1
r value	1.000e+02
v drop	-1.441e-05
current	-1.441e-07
power	2.075e-12

\*\*\*\* mosfets

subckt

element	0:mb1	0:mb2	0:mb3	0:mb4	0:mi1	0:mi2
model	0:cmosp	0:cmosp	0:cmosn	0:cmosn	0:cmosp	0:cmosp
id	-2.659e-05	-2.670e-05	2.659e-05	2.659e-05	-1.335e-05	-1.335e-05
ibs	0.	0.	0.	-1.472e-14	0.	0.
ibd	8.027e-15	1.228e-14	-1.472e-14	-3.197e-14	2.023e-14	2.003e-14
vgs	-8.027e-01	-8.027e-01	1.471e+00	1.725e+00	-7.723e-01	-7.724e-01
vds	-8.027e-01	-1.227e+00	1.471e+00	1.725e+00	-2.023e+00	-2.003e+00
vbs	0.	0.	0.	-1.471e+00	0.	0.
vth	-7.000e-01	-7.000e-01	7.000e-01	9.548e-01	-7.000e-01	-7.000e-01
vdsat	-1.027e-01	-1.027e-01	7.717e-01	7.708e-01	-7.235e-02	-7.236e-02
beta	5.040e-03	5.061e-03	8.930e-05	8.952e-05	5.101e-03	5.100e-03
gam eff	7.000e-01	7.000e-01	4.000e-01	4.000e-01	7.000e-01	7.000e-01
gm	5.177e-04	5.199e-04	6.891e-05	6.900e-05	3.690e-04	3.690e-04
gds	2.638e-07	2.638e-07	2.620e-07	2.614e-07	1.308e-07	1.309e-07
gmb	2.026e-04	2.034e-04	1.647e-05	9.364e-06	1.444e-04	1.444e-04
cdtot	1.478e-28	2.261e-28	0.	0.	3.726e-28	3.689e-28
cgtot	9.856e-26	9.864e-26	4.651e-27	4.641e-27	1.009e-25	1.009e-25
cstot	9.208e-26	9.208e-26	4.604e-27	4.604e-27	9.208e-26	9.208e-26
cbtot	6.331e-27	6.331e-27	0.	0.	8.414e-27	8.412e-27
cgs	9.208e-26	9.208e-26	4.604e-27	4.604e-27	9.208e-26	9.208e-26
cgd	1.478e-28	2.261e-28	0.	0.	3.726e-28	3.689e-28

subckt

element	0:m11	0:m12	0:m21	0:m22	0:mr1	0:mr2
model	0:cmosn	0:cmosn	0:cmosn	0:cmosp	0:cmosp	0:cmosn
id	1.335e-05	1.335e-05	2.682e-05	-2.682e-05	1.100e-05	1.582e-05
ibs	0.	0.	0.	0.	2.364e-14	-1.636e-14
ibd	-7.491e-15	-7.693e-15	-1.636e-14	1.682e-14	1.682e-14	-2.318e-14

vgs	7.491e-01	7.491e-01	7.693e-01	-8.027e-01	-1.635e+00	2.364e+00
vds	7.491e-01	7.693e-01	1.635e+00	-1.681e+00	6.826e-01	6.826e-01
vbs	0.	0.	0.	0.	2.364e+00	-1.635e+00
vth	7.000e-01	7.000e-01	7.000e-01	-7.000e-01	-1.176e+00	9.767e-01
vdsat	4.908e-02	4.908e-02	6.927e-02	-1.027e-01	-6.826e-01	6.826e-01
beta	1.108e-02	1.108e-02	1.118e-02	5.084e-03	2.014e-05	2.215e-05
gam eff	4.000e-01	4.000e-01	4.000e-01	7.000e-01	7.000e-01	4.000e-01
gm	5.440e-04	5.441e-04	7.744e-04	5.222e-04	1.375e-05	1.512e-05
gds	1.325e-07	1.325e-07	2.639e-07	2.638e-07	9.357e-06	1.577e-05
gmb	1.300e-04	1.301e-04	1.851e-04	2.044e-04	3.054e-06	1.979e-06
cdtot	1.380e-28	1.417e-28	3.013e-28	3.097e-28	3.380e-26	1.032e-26
cgtot	9.994e-26	9.994e-26	9.836e-26	9.873e-26	5.208e-26	2.669e-26
cstot	9.208e-26	9.208e-26	9.208e-26	9.208e-26	1.810e-26	1.633e-26
cbtot	7.715e-27	7.715e-27	5.970e-27	6.331e-27	1.729e-28	0.
cgs	9.208e-26	9.208e-26	9.208e-26	9.208e-26	1.810e-26	1.633e-26
cgd	1.380e-28	1.417e-28	3.013e-28	3.097e-28	3.380e-26	1.032e-26

```

subckt
element 0:mout1 0:mout2
model 0:cmosn 0:cmosp
id 2.457e-03 -2.457e-03
ibs 0. 0.
ibd -2.000e-14 2.000e-14
vgs 1.635e+00 -1.681e+00
vds 2.000e+00 -2.000e+00
vbs 0. 0.
vth 7.000e-01 -7.000e-01
vdsat 9.359e-01 -9.815e-01
beta 5.610e-03 5.100e-03
gam eff 4.000e-01 7.000e-01
gm 5.250e-03 5.006e-03
gds 2.409e-05 2.408e-05
gmb 1.255e-03 1.959e-03
cdtot 1.842e-28 3.683e-28
cgtot 4.651e-26 9.323e-26
cstot 4.604e-26 9.208e-26
cbtot 2.788e-28 7.758e-28
cgs 4.604e-26 9.208e-26
cgd 1.842e-28 3.683e-28

```

Opening plot unit= 15  
file=./buffer.tr0

```

*****
*current source
***** transient analysis tnom= 25.000 temp= 25.000
*****
current_vdd = -4.5829E-03 from= .0000E+00 to= 5.0000E-05
power_vdd = -1.8332E-02

```

*average power dissipation*

```

***** job concluded
***** Star-HSPICE -- 97.2.1 (970915) 14:15:30 98/06/01 pa
*****

```

```

*current source
***** job statistics summary tnom= 25.000 temp= 25.000
*****

```

total memory used 159 kbytes

# nodes = 12 # elements= 19

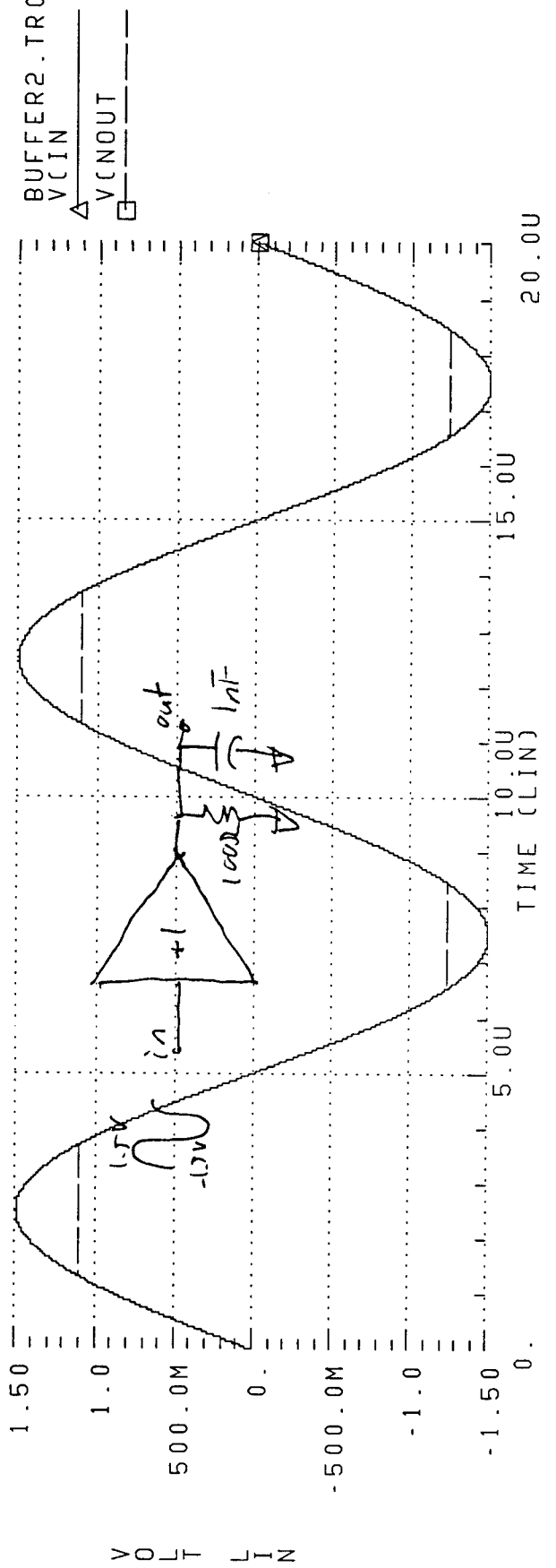
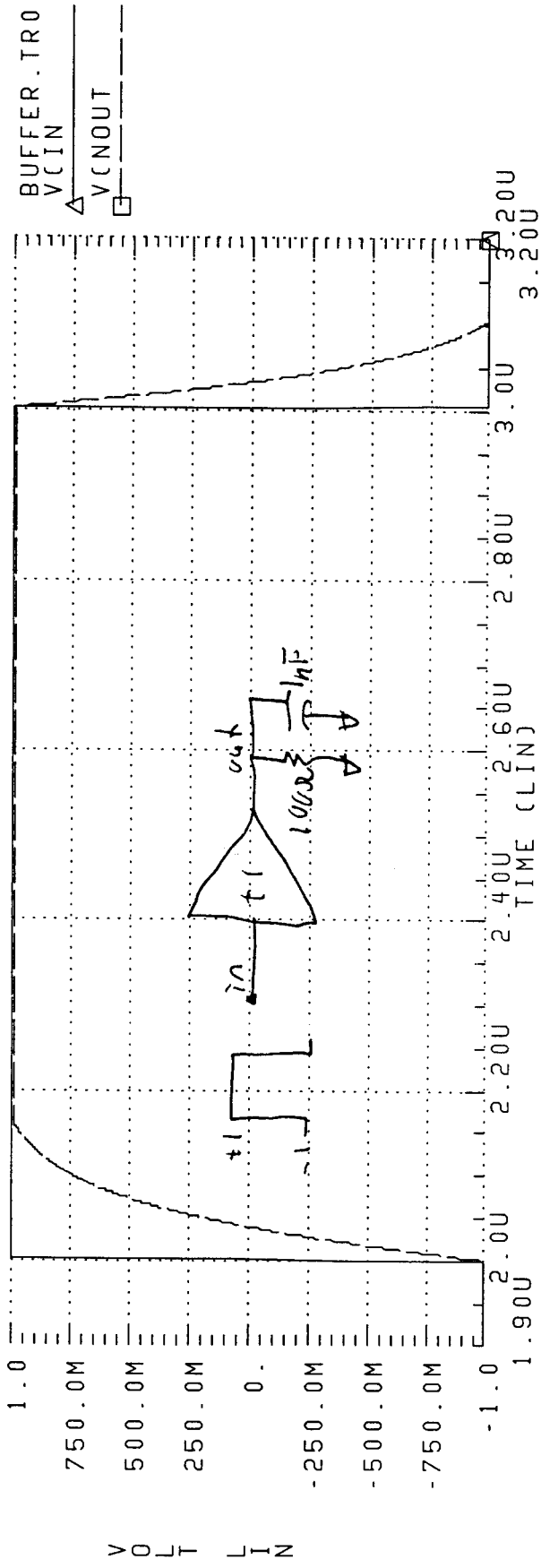
# diodes= 0 # bjts = 0 # jfets = 0 # mosfets = 14

analysis	time	# points	tot. iter	conv.iter
op point	.11	1	7	
transient	214.78	51	200387	100051 rev= 27
readin	.10			
errchk	.08			
setup	.00			
output	1.55			

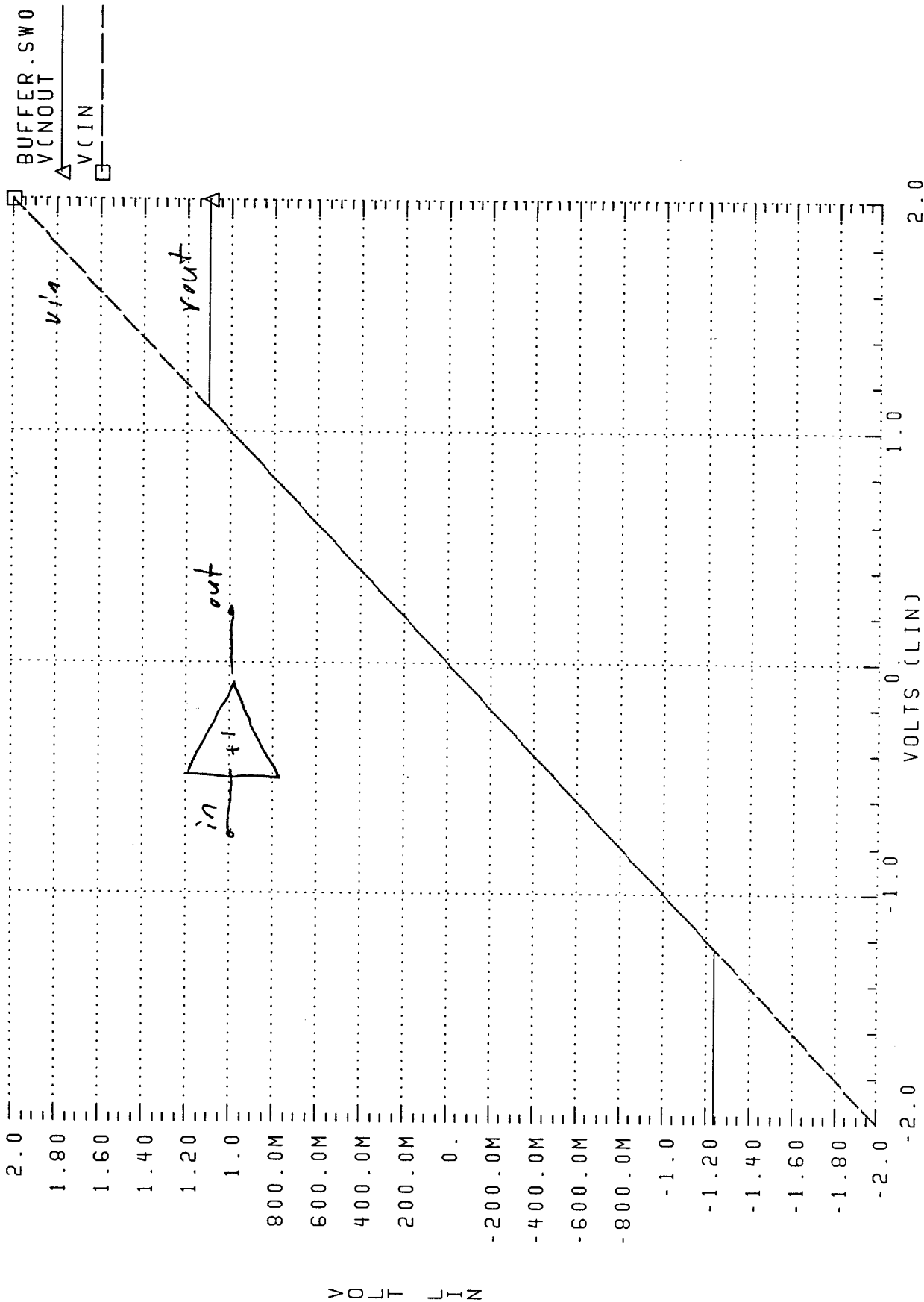
total cpu time 216.72 seconds  
job started at 14:15:30 98/06/01  
job ended at 14:19:15 98/06/01

lic: Release token(s)  
HSPICE job buffer.sp completed.  
Mon Jun 1 14:19:15 PDT 1998

OUTPUT BUFFER



# OUTPUT BUFFER



BUFFER.SW0  
VCNOUT  
VCIN

