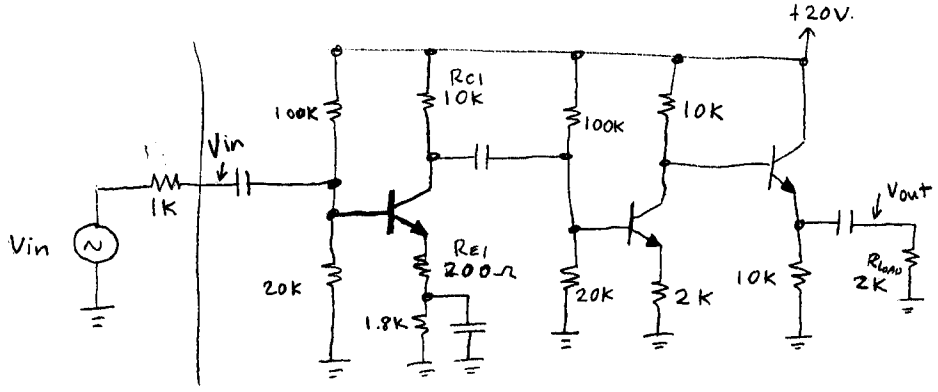
Multi-stage amplifier analysis – Example

(It's just a bunch of single stage amplifiers connected together)

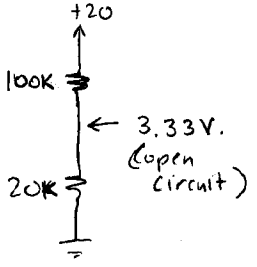


All transistors → β=200

① Find Bias point

Stage 1:

First – Approximate it:



If $\beta = \infty$

$V_B = 3.33$

$\Rightarrow V_E = V_B - .7 = 2.63$

$\Rightarrow I_E = \frac{V_E}{R_E} = \frac{2.63}{2000} = 1.32\ mA$

$V_{RC} = I_C R_C = (1.32\ ma)(10K)$

$= 13.2$ volts

$V_C = V_{CC} - V_{RC} = 20 - 13.2$

$= 6.83$ volts

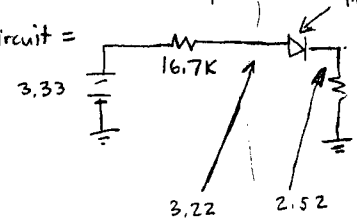
$V_{CE} = V_C - V_E = 6.83 - 2.63$

$= 4.20$ volts

This is a poor design!

More accurate analysis:

Bias circuit =



$V_E = 2.52$

$I_E = \frac{V_E}{R_E} = \frac{2.52}{2000} = 1.26\ mA$

$I_C = \alpha I_E = \frac{\beta}{\beta+1} I_E = 1.25\ mA.$ $\quad I_B = \frac{1.25}{200}\ ma = 6.25\ uA$

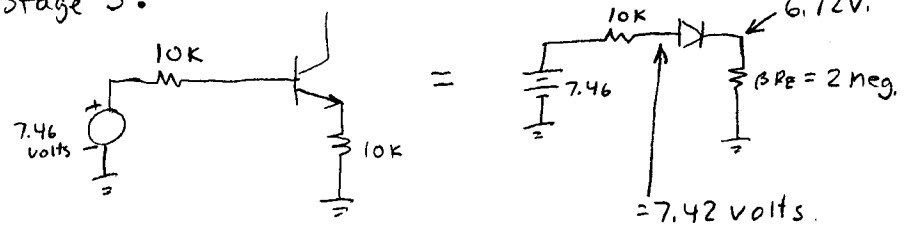
$V_{RC} = I_C R_C = (1.25\ mA)(10K\Omega) = 12.5$ volts

$V_C = V_{CC} - V_{RC} = 20 - 12.5 = 7.46$ volts.

$V_{CE} = V_C - V_E = 7.46 - 2.52 = 4.94$ volts.

Stage 2: Same except for load of third stage

Stage 3:



$V_{CE} = 20 - 6.72 = 13.28$

$V_E = 6.72V.$

$I_E = \frac{V_E}{R_E} = .672\ ma$

V_C of stage 2 drops to 7.42 volts, (not significant).

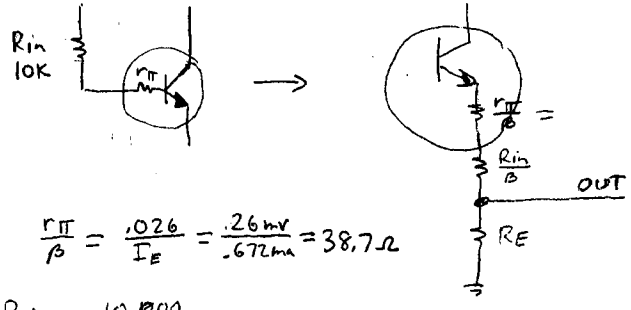
② Find g_m, $\frac{r_\pi}{\beta} = \frac{r_\pi}{\beta} = \frac{.026}{I_E} = 20.8\ \Omega$

$g_m = \frac{1}{20.8} = .0481\ \frac{A}{V}$

(2) Find Rout for all stages

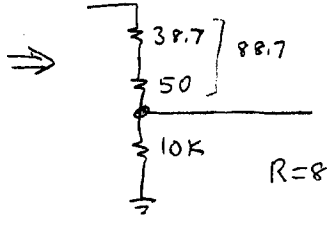
Stage 1, 2 : 10K

Stage 3: Emitter follower ---



Stage 3 $\frac{r_\pi}{\beta} = \frac{.026}{I_E} = \frac{.26mv}{.672ma} = 38.7\Omega$

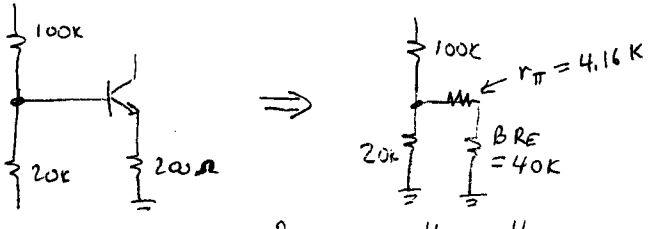
$\frac{R_{in}}{\beta} = \frac{10000}{200} = 50$



R = 87.9 Ω

(3) Find Rin, all stages

Stage 1:

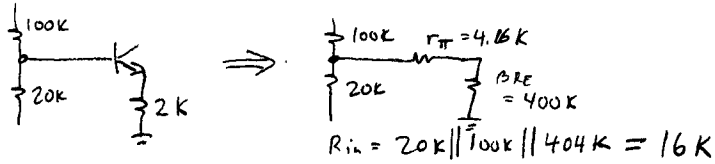


$r_\pi = \frac{26mv}{I_B} = \frac{26 \times 10^{-3}}{6.25 \times 10^{-6}} = 4.16K$

$R_{in} = 20K \,||\, 100K \,||\, 44K$

$= 12.1K$

Stage 2:



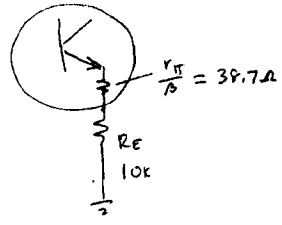
$R_{in} = 20K \,||\, 100K \,||\, 404K = 16K$

Rin ----

Stage 3: It is an emitter follower.

Rin depends on the load

No load:



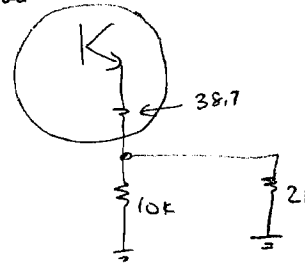
$R_{E\text{-effective}} = 10K + 38.7 = 10039$

Reflect thru ---

$R_{in} = (10039)(\beta)$

$= 2$ meg.

With 2K load

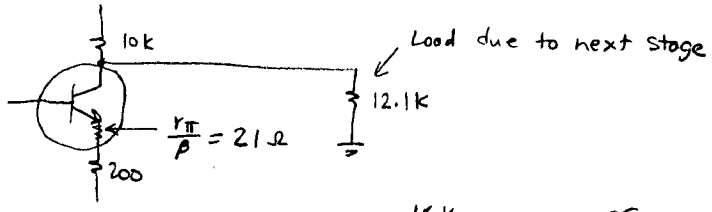


$R_{E\text{ effective}} = 1705$

$R_{in} = (1705)(\beta) = 341.1K.$

(4) Find Gain, each stage

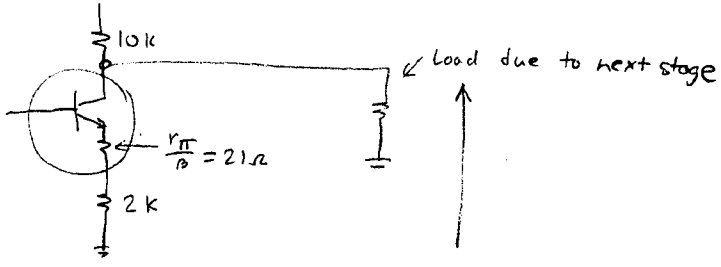
Stage 1:



Voltage Gain $= -\frac{R_{C\,effective}}{R_{E\,effective}} = \frac{-10K \,\|\, 16K}{200+21} = -\frac{6155}{221}$

$= -27.85$

Stage 2:



The next stage is an emitter follower — Its Rin depends on the load.

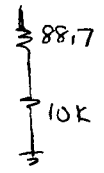
No load:
Voltage Gain $= -\frac{10K \,\|\, 2\,meg}{2021} = \frac{-9950}{2021} = -4.923$

With load:
Voltage Gain $= -\frac{10K \,\|\, 341K}{2021} = \frac{-9715}{2021} = -4.807$

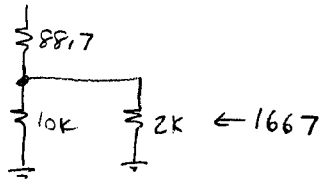
Use the No load gain, because we will account for the drop in the next stage.

Stage 3

No load



With load



Voltage divider:

$\frac{10K}{10K+89} = .991$

$\frac{1667}{1667+89} = .949$

Overall voltage gain = product of gains

$\frac{V_{out}}{V_{in}} = \left(\frac{-24.8}{-27.85}\right)(-4.92)(.991) = \frac{120.9}{135.8}$ (No load)

$\frac{V_{out}}{V_{in}} = \left(\frac{-24.8}{-27.85}\right)(-4.92)(.949) = \frac{115.8}{130}$ (2K load)

Current gain:

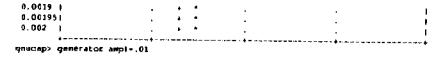
$\frac{I_{out}}{I_{in}} = \frac{\frac{V_{out}}{R_{LOAD}}}{\frac{V_{in}}{R_{in}}} = \frac{V_{out}}{V_{in}}\frac{R_{in}}{R_{LOAD}} = \left(\frac{130}{115.8}\right)\frac{12.1K}{2K}$

$= \left(\frac{130}{115.8}\right)(6.05) = \frac{786.7}{700.6}$

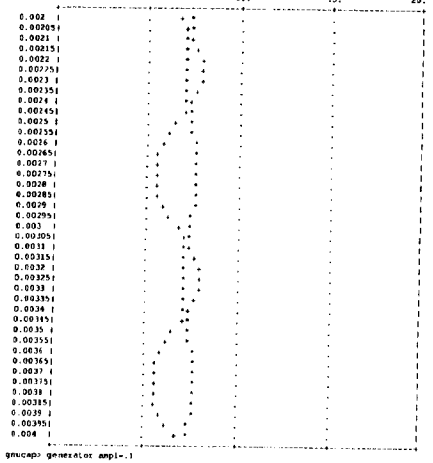
Power gain = Voltage gain × current gain

$= \left(\frac{115.8}{130}\right)\left(\frac{700.6}{786.7}\right) = \frac{81128}{102.3 \times 10^3}$

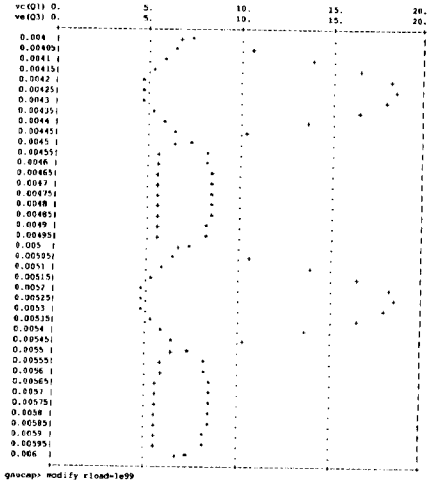
```
Script started on Fri Apr 15 02:10:40 2005
al@hobbes:/home/al/kettering/e2/02c>gd
Gnucap 2005.03.20 RCS 25.15
The Gnu Circuit Analysis Package
Never trust any version less than 1.0
Copyright 1982-2002, Albert Davis
Gnucap comes with ABSOLUTELY NO WARRANTY
This is free software, and you are welcome
to redistribute it under certain conditions
according to the GNU General Public License.
See the file "COPYING" for details.
gnucap> get output.net

* gnetlist -g spice-sdb schematic.sch
gnucap> list

************************************************************
* Spice file generated by gnetlist                         *
* spice-sdb version 10.9.2004 by SDB --                    *
* provides advanced spice netlisting capability.           *
* Documentation at http://www.brorson.com/gEDA/SPICE/      *
************************************************************
R5 ( 0 11 )  1.8K
Q3 ( 7 5 8 )  2N3904  area= 1.
R4 ( 11 3 )  200.
Q2 ( 5 4 6 )  2N3904  area= 1.
R3 ( 2 7 )  10.K
Q1 ( 2 1 3 )  2N3904  area= 1.
R2 ( 0 1 )  20.K
C5 ( 7 0 )  10.u
Rload ( 0 10 )  2.K
R1 ( 1 7 )  100.K
Rs ( 12 9 )  1.K
C4 ( 8 10 )  10.u
C3 ( 2 4 )  10.u
C2 ( 11 0 )  100.u
Vcc ( 7 0 )  DC  20.
R10 ( 0 8 )  10.K
R9 ( 0 6 )  2.K
C1 ( 9 1 )  10.u
Vin ( 12 0 ) GENERATOR
R8 ( 5 7 )  10.K
R7 ( 0 4 )  20.K
R6 ( 4 7 )  100.K
.END
gnucap> build

>.model 2n3904 npn bf=200

>

gnucap> list

************************************************************
* Spice file generated by gnetlist                         *
* spice-sdb version 10.9.2004 by SDB --                    *
* provides advanced spice netlisting capability.           *
* Documentation at http://www.brorson.com/gEDA/SPICE/      *
************************************************************
R5 ( 0 11 )  1.8K
Q3 ( 7 5 8 )  2N3904  area= 1.
R4 ( 11 3 )  200.
Q2 ( 5 4 6 )  2N3904  area= 1.
R3 ( 2 7 )  10.K
Q1 ( 2 1 3 )  2N3904  area= 1.
R2 ( 0 1 )  20.K
C5 ( 7 0 )  10.u
Rload ( 0 10 )  2.K
R1 ( 1 7 )  100.K
Rs ( 12 9 )  1.K
C4 ( 8 10 )  10.u
C3 ( 2 4 )  10.u
C2 ( 11 0 )  100.u
Vcc ( 7 0 )  DC  20.
R10 ( 0 8 )  10.K
R9 ( 0 6 )  2.K
C1 ( 9 1 )  10.u
Vin ( 12 0 ) GENERATOR
R8 ( 5 7 )  10.K
R7 ( 0 4 )  20.K
R6 ( 4 7 )  100.K
.END
.model  2n3904  npn  (level=1  kf= 0.  af= 1.  bf= 200.  br= 1.  is= 100.E-18  nf= 1.  nr= 1
.  isc= 0.  c4= 0.  nc= 2.  ise= 0.  c2= 0.  ne= 1.5  rb= 0.  rbm= 0.  re= 0.  rc= 0.  cjc=
0.  cje= 0.  cjs= 0.  fc= 0.5  mjc= 0.33  mje= 0.33  mjs= 0.  vjc= 0.75  vje= 0.75  vjs= 0.7
5  xcjc= 1.  itf= 0.  ptf= 0.  tf= 0.  tr= 0.  xtf= 0.  xtb= 0.  xti= 3.  eg= 1.11)
*+()
gnucap> print op vce(q*)

gnucap> op

#           vce(Q3)     vce(Q2)     vce(Q1)
 300.15     13.         5.3123      5.3471
gnucap> print op vbe(q*)

gnucap> op

#           vbe(Q3)     vbe(Q2)     vbe(Q1)
 300.15     0.76485     0.77935     0.77935
gnucap> del 2n3904

gnucap> build

>.model 2n3904 npn bf=200 is=10e-15

>

gnucap> op

#           vbe(Q3)     vbe(Q2)     vbe(Q1)
 300.15     0.64406     0.66141     0.66141

gnucap> del 2n3904

gnucap> build

>.model 2n3904 npn bf=200 is=1e-15

>

gnucap> op

#           vbe(Q3)     vbe(Q2)     vbe(Q1)
 300.15     0.70447     0.72039     0.72039

gnucap> del 2n3904

gnucap> build

>.model 2n3904 npn bf=200 is=2e-15

>

gnucap> op

#           vbe(Q3)     vbe(Q2)     vbe(Q1)
 300.15     0.68629     0.70264     0.70264
gnucap> print op vce(q*)

gnucap> op

#           vce(Q3)     vce(Q2)     vce(Q1)
 300.15     13.287      4.8736      4.907
gnucap> print op gm(q*)

gnucap> op

#           gm(Q3)      gm(Q2)      gm(Q1)
 300.15     0.025827    0.048589    0.048589
gnucap> print ac v nodes

gnucap> ac 1k

#Freq       v(1)        v(2)        v(3)        v(4)        v(5)        v(6)        v(7)        v(8
)       v(9)        v(10)       v(11)       v(12)
 1.K       0.92373     25.659      0.83794     25.659      122.78      25.399      621.8n      120
.01      0.92373     120.        0.0066678   1.
gnucap> modify rload=1e99

gnucap> op

#           gm(Q3)      gm(Q2)      gm(Q1)
 300.15     0.025827    0.048589    0.048589
gnucap> ac

#Freq       v(1)        v(2)        v(3)        v(4)        v(5)        v(6)        v(7)        v(8
)       v(9)        v(10)       v(11)       v(12)
 1.K       0.92373     25.659      0.83794     25.659      125.74      25.399      27.027n     125
.26      0.92373     125.26      0.0066678   1.
gnucap> print ac z(rload) z(vin)

gnucap> ac

#Freq       z(Rload)    z(Vin)
 1.K       88.941      13.112K
gnucap> modify rload=2k

gnucap> op

#           gm(Q3)      gm(Q2)      gm(Q1)
 300.15     0.025827    0.048589    0.048589
gnucap> ac

#Freq       z(Rload)    z(Vin)
 1.K       88.941      13.112K
gnucap> wpdth out=80

gnucap> generator

freq= 0.  ampl= 1.  phase= 0.  max= 1.  min= 0.  offset= 0.  init= 0.
+  rise= 1.p  fall= 1.p  delay= 0.  width= 0.  period= 0.
gnucap> generator freq=1k ampl=.001

gnucap> plot tran vc(q1)(0,20) ve(q3)(0,20)

gnucap> tran 0 .002 .00005

vc(Q1) 0.                5.                10.               15.               20.
ve(Q3) 0.                5.                10.               15.               20.
       +-----------------+-----------------+-----------------+-----------------+
0.     |                  .    +  *         .                 .                 |
50.u   |                  .     + *         .                 .                 |
100.u  |                  .     + *         .                 .                 |
150.u  |                  .     + *         .                 .                 |
200.u  |                  .     + *         .                 .                 |
250.u  |                  .     + *         .                 .                 |
300.u  |                  .     + *         .                 .                 |
350.u  |                  .     + *         .                 .                 |
400.u  |                  .     + *         .                 .                 |
450.u  |                  .     + *         .                 .                 |
500.u  |                  .    +  *         .                 .                 |
550.u  |                  .    +  *         .                 .                 |
600.u  |                  .    +  *         .                 .                 |
650.u  |                  .    +  *         .                 .                 |
700.u  |                  .    +  *         .                 .                 |
750.u  |                  .    +  *         .                 .                 |
800.u  |                  .    +  *         .                 .                 |
850.u  |                  .    +  *         .                 .                 |
900.u  |                  .    +  *         .                 .                 |
950.u  |                  .    +  *         .                 .                 |
0.001  |                  .    +  *         .                 .                 |
0.00105|                  .     + *         .                 .                 |
0.0011 |                  .     + *         .                 .                 |
0.00115|                  .     + *         .                 .                 |
0.0012 |                  .     + *         .                 .                 |
0.00125|                  .     + *         .                 .                 |
0.0013 |                  .     + *         .                 .                 |
0.00135|                  .     + *         .                 .                 |
0.0014 |                  .     + *         .                 .                 |
0.00145|                  .     + *         .                 .                 |
0.0015 |                  .    +  *         .                 .                 |
0.00155|                  .    +  *         .                 .                 |
0.0016 |                  .    +  *         .                 .                 |
0.00165|                  .    +  *         .                 .                 |
0.0017 |                  .    +  *         .                 .                 |
0.00175|                  .    +  *         .                 .                 |
0.0018 |                  .    +  *         .                 .                 |
0.00185|                  .    +  *         .                 .                 |
```



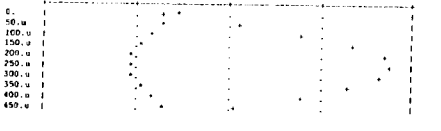
```
gnucap> generator ampl=.01

gnucap> tran
```

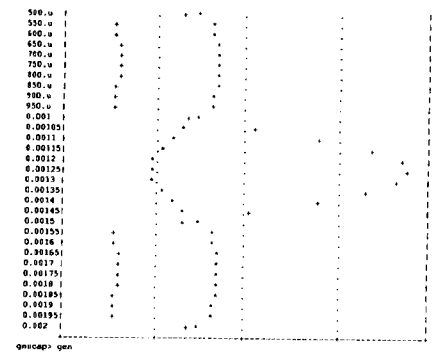


```
gnucap> generator ampl=.1

gnucap> tran
```

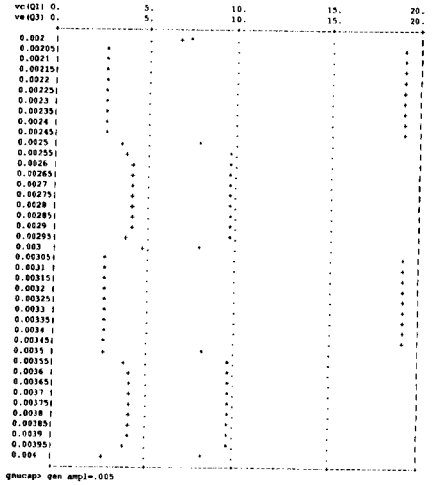


```
gnucap> modify rload=1e99

gnucap> tran
```

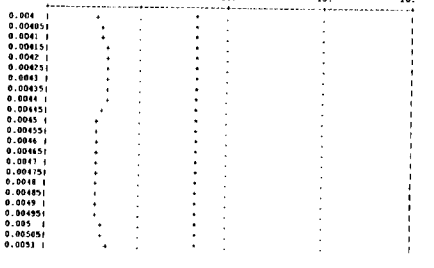


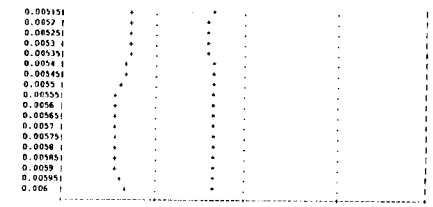


```
gnucap> gen

freq= 1.K  ampl= 0.1  phase= 0.  max= 1.  min= 0.  offset= 0.
+  init= 0.  rise= 1.p  fall= 1.p  delay= 0.  width= 0.  period= 0.
gnucap> gen ampl=1

gnucap> tran
```

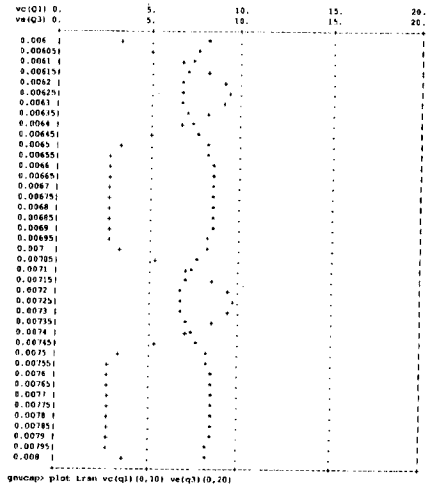


```
gnucap> gen ampl=.005

gnucap> ac

#Freq       z(Rload)    z(Vin)
 1.K        122.16      13.149K
gnucap> tran
```

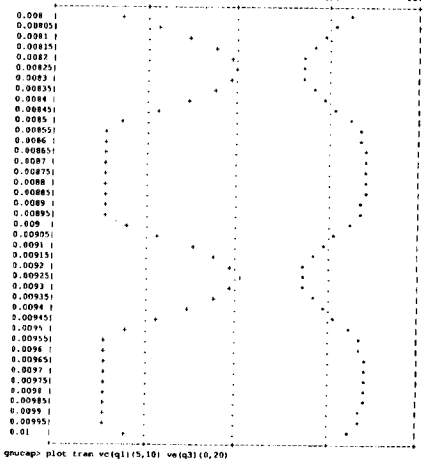




```
gnucap> generator ampl=.05

gnucap> tran
```

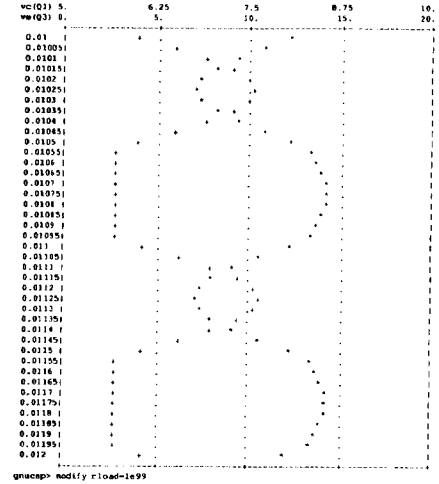


```
gnucap> plot tran vc(q1)(0,10) ve(q3)(0,20)

gnucap> tran
```

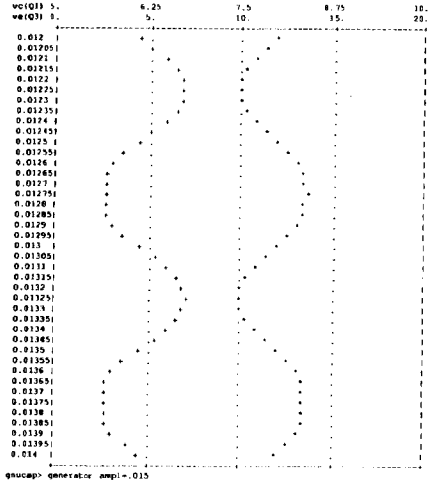


```
gnucap> plot tran vc(q1)(5,10) ve(q3)(0,20)
```

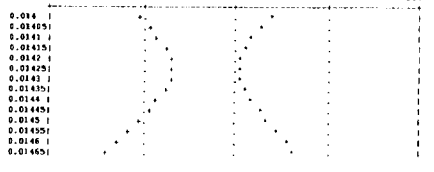
```
gnucap> tran
```

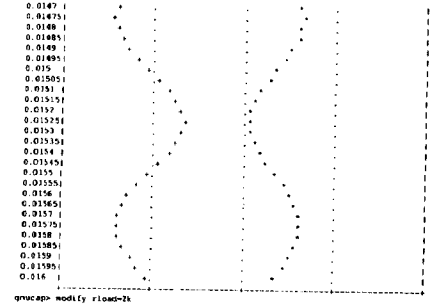


```
gnucap> modify rload=1e99

gnucap> generator ampl=.02

gnucap> tran
```



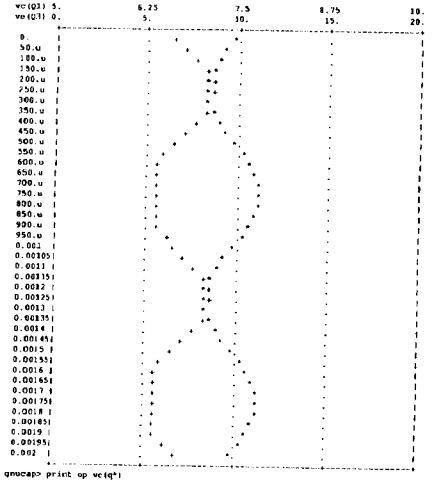
```
gnucap> generator ampl=.015

gnucap> tran
```



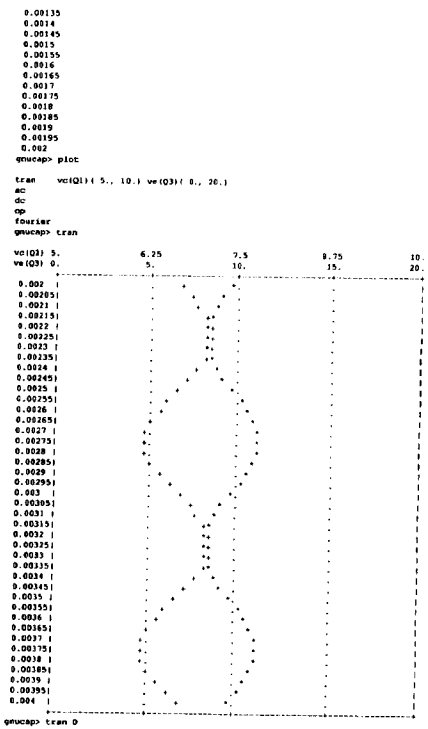


```
gnucap> modify rload=2k
```

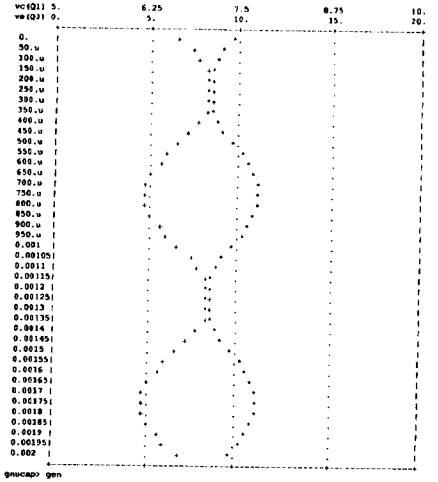
```
gnucap> tran
```



```
gnucap> print op vc(q*)

gnucap> op

#              vc(Q3)      vc(Q2)      vc(Q1)
  300.15          20.      7.3996       7.433
gnucap> modify rload=1e99

gnucap> op

#              vc(Q3)      vc(Q2)      vc(Q1)
  300.15          20.      7.3996       7.433
gnucap> tran

#Time
0.
50.u
100.u
150.u
200.u
250.u
300.u
350.u
400.u
450.u
500.u
550.u
600.u
650.u
700.u
750.u
800.u
850.u
900.u
950.u
0.001
0.00105
0.0011
0.00115
0.0012
0.00125
0.0013
```

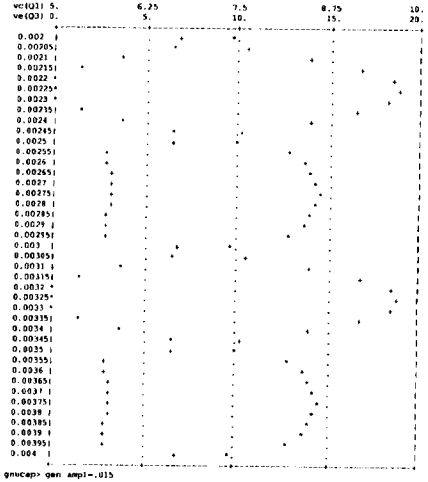


```
gnucap> tran 0
```

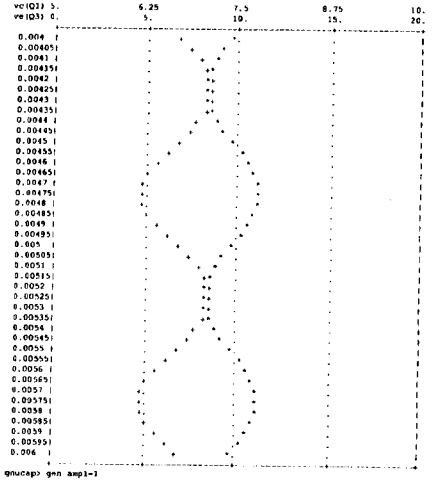


```
gnucap> gen

freq= 1.K  ampl= 0.015  phase= 0.  max= 1.  min= 0.  offset= 0.
+ init= 0.  rise= 1.p  fall= 1.p  delay= 0.  width= 0.  period= 0.
```

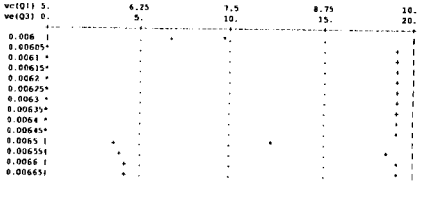
```
gnucap> gen ampl=.1

gnucap> tran
```

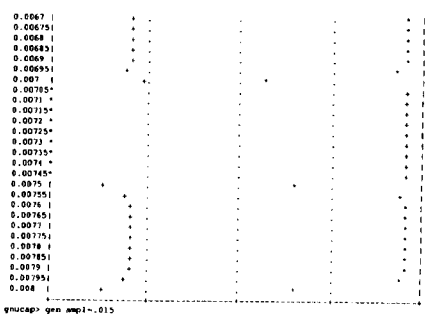


```
gnucap> gen ampl=.015

gnucap> tran
```

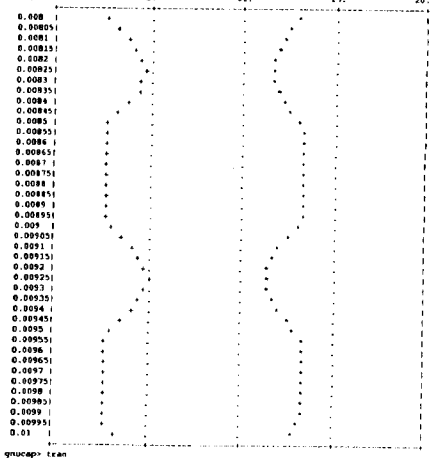


```
gnucap> gen ampl=1

gnucap> tran
```

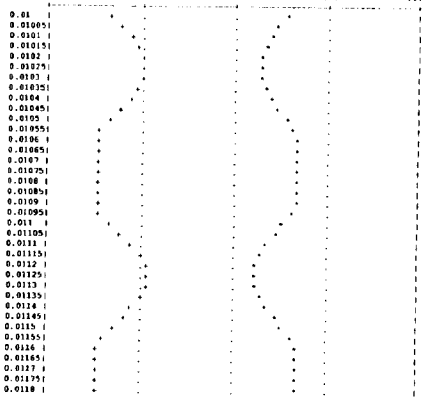




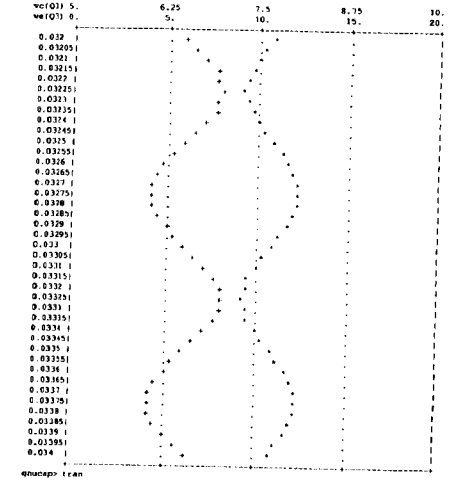
```
gnucap> gen ampl=.015

gnucap> tran
```

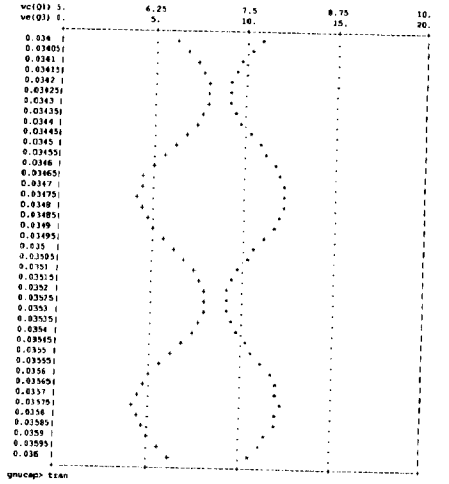


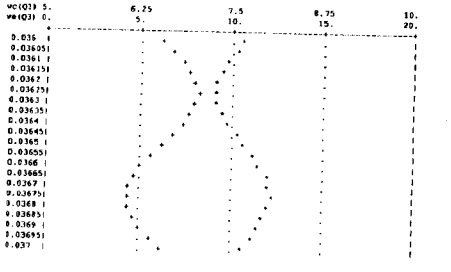
```
gnucap> tran
```

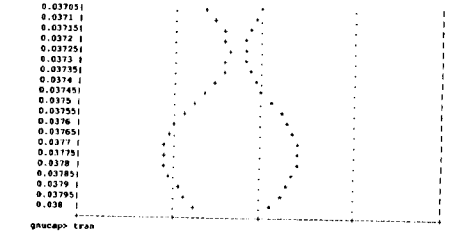


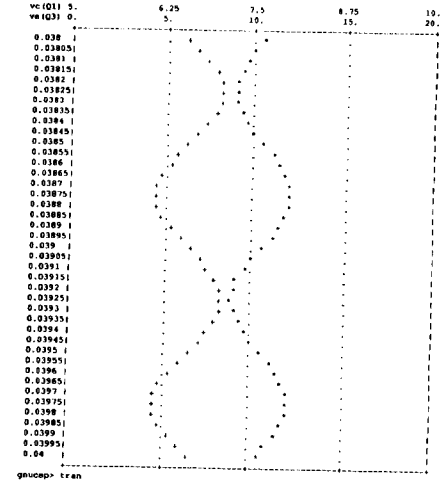
```
0.01185|
0.0119 |
0.01195|
0.012  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.012  |
0.01205|
0.0121 |
0.01215|
0.0122 |
0.01225|
0.0123 |
0.01235|
0.0124 |
0.01245|
0.0125 |
0.01255|
0.0126 |
0.01265|
0.0127 |
0.01275|
0.0128 |
0.01285|
0.0129 |
0.01295|
0.013  |
0.01305|
0.0131 |
0.01315|
0.0132 |
0.01325|
0.0133 |
0.01335|
0.0134 |
0.01345|
0.0135 |
0.01355|
0.0136 |
0.01365|
0.0137 |
0.01375|
0.0138 |
0.01385|
0.0139 |
0.01395|
0.014  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.014  |
0.01405|
0.0141 |
0.01415|
0.0142 |
0.01425|
0.0143 |
0.01435|
0.0144 |
0.01445|
0.0145 |
0.01455|
0.0146 |
0.01465|
0.0147 |
0.01475|
0.0148 |
0.01485|
0.0149 |
0.01495|
0.015  |
0.01505|
0.0151 |
0.01515|
0.0152 |
0.01525|
0.0153 |
0.01535|
0.0154 |
0.01545|
0.0155 |
0.01555|
0.0156 |
0.01565|
0.0157 |
0.01575|
0.0158 |
0.01585|
0.0159 |
0.01595|
0.016  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.016  |
0.01605|
0.0161 |
0.01615|
0.0162 |
0.01625|
0.0163 |
0.01635|
0.0164 |
0.01645|
0.0165 |
0.01655|
0.0166 |
0.01665|
0.0167 |
0.01675|
0.0168 |
0.01685|
0.0169 |
0.01695|
0.017  |
0.01705|
0.0171 |
0.01715|
0.0172 |
0.01725|
0.0173 |
0.01735|
0.0174 |
0.01745|
0.0175 |
0.01755|
0.0176 |
0.01765|
0.0177 |
0.01775|
0.0178 |
0.01785|
0.0179 |
0.01795|
0.018  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.018  |
0.01805|
0.0181 |
0.01815|
0.0182 |
0.01825|
0.0183 |
0.01835|
0.0184 |
0.01845|
0.0185 |
0.01855|
0.0186 |
0.01865|
0.0187 |
0.01875|
0.0188 |
0.01885|
0.0189 |
0.01895|
0.019  |
0.01905|
0.0191 |
0.01915|
0.0192 |
0.01925|
0.0193 |
0.01935|
0.0194 |
0.01945|
0.0195 |
0.01955|
0.0196 |
0.01965|
0.0197 |
0.01975|
0.0198 |
0.01985|
0.0199 |
0.01995|
0.02   |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.02   |
0.02005|
0.0201 |
0.02015|
0.0202 |
0.02025|
0.0203 |
0.02035|
0.0204 |
0.02045|
0.0205 |
0.02055|
0.0206 |
0.02065|
0.0207 |
0.02075|
0.0208 |
0.02085|
0.0209 |
0.02095|
0.021  |
0.02105|
0.0211 |
0.02115|
0.0212 |
0.02125|
0.0213 |
0.02135|
0.0214 |
0.02145|
0.0215 |
0.02155|
0.0216 |
0.02165|
0.0217 |
0.02175|
0.0218 |
0.02185|
0.0219 |
0.02195|
0.022  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.022  |
0.02205|
0.0221 |
0.02215|
0.0222 |
0.02225|
0.0223 |
0.02235|
0.0224 |
0.02245|
0.0225 |
0.02255|
0.0226 |
0.02265|
0.0227 |
0.02275|
0.0228 |
0.02285|
0.0229 |
0.02295|
0.023  |
0.02305|
0.0231 |
0.02315|
0.0232 |
0.02325|
0.0233 |
0.02335|
0.0234 |
0.02345|
0.0235 |
0.02355|
0.0236 |
0.02365|
0.0237 |
0.02375|
0.0238 |
0.02385|
0.0239 |
0.02395|
0.024  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.024  |
0.02405|
0.0241 |
0.02415|
0.0242 |
0.02425|
0.0243 |
0.02435|
0.0244 |
0.02445|
0.0245 |
0.02455|
0.0246 |
0.02465|
0.0247 |
0.02475|
0.0248 |
0.02485|
0.0249 |
0.02495|
0.025  |
0.02505|
0.0251 |
0.02515|
0.0252 |
0.02525|
0.0253 |
0.02535|
0.0254 |
0.02545|
0.0255 |
0.02555|
0.0256 |
0.02565|
0.0257 |
0.02575|
0.0258 |
0.02585|
0.0259 |
0.02595|
0.026  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.026  |
0.02605|
0.0261 |
0.02615|
0.0262 |
0.02625|
0.0263 |
0.02635|
0.0264 |
0.02645|
0.0265 |
0.02655|
0.0266 |
0.02665|
0.0267 |
0.02675|
0.0268 |
0.02685|
0.0269 |
0.02695|
0.027  |
0.02705|
0.0271 |
0.02715|
0.0272 |
0.02725|
0.0273 |
0.02735|
0.0274 |
0.02745|
0.0275 |
0.02755|
0.0276 |
0.02765|
0.0277 |
0.02775|
0.0278 |
0.02785|
0.0279 |
0.02795|
0.028  |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.028  |
0.02805|
0.0281 |
0.02815|
0.0282 |
0.02825|
0.0283 |
0.02835|
0.0284 |
0.02845|
0.0285 |
0.02855|
0.0286 |
0.02865|
0.0287 |
0.02875|
0.0288 |
0.02885|
0.0289 |
0.02895|
0.029  |
0.02905|
0.0291 |
0.02915|
0.0292 |
0.02925|
0.0293 |
0.02935|
0.0294 |
0.02945|
0.0295 |
0.02955|
0.0296 |
0.02965|
0.0297 |
0.02975|
0.0298 |
0.02985|
0.0299 |
0.02995|
0.03   |
gnucap> tran
vc(Q1) 5.      6.25      7.5      8.75      10.
vc(Q3) 0.      5.        10.      15.       20.
0.03   |
0.03005|
0.0301 |
0.03015|
0.0302 |
0.03025|
0.0303 |
0.03035|
0.0304 |
0.03045|
0.0305 |
0.03055|
0.0306 |
0.03065|
0.0307 |
0.03075|
0.0308 |
0.03085|
0.0309 |
0.03095|
0.031  |
0.03105|
0.0311 |
0.03115|
0.0312 |
0.03125|
0.0313 |
0.03135|
0.0314 |
0.03145|
0.0315 |
0.03155|
0.0316 |
0.03165|
0.0317 |
0.03175|
0.0318 |
0.03185|
0.0319 |
0.03195|
0.032  |
gnucap> tran
```

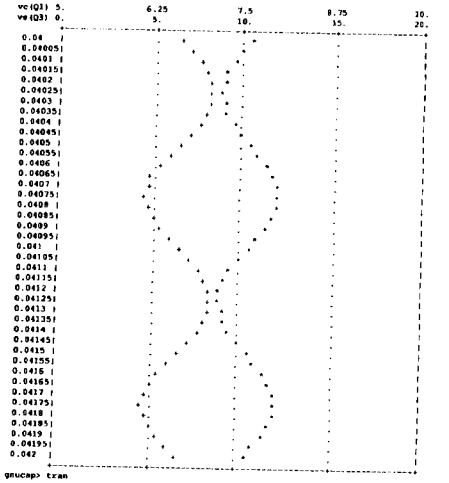

vc(Q3) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran

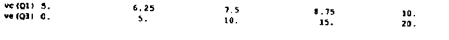

vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran

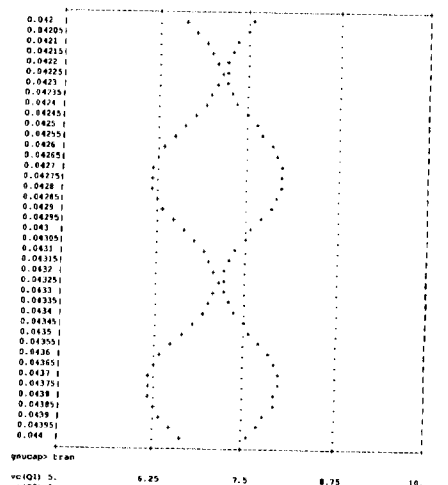

vc(Q3) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.

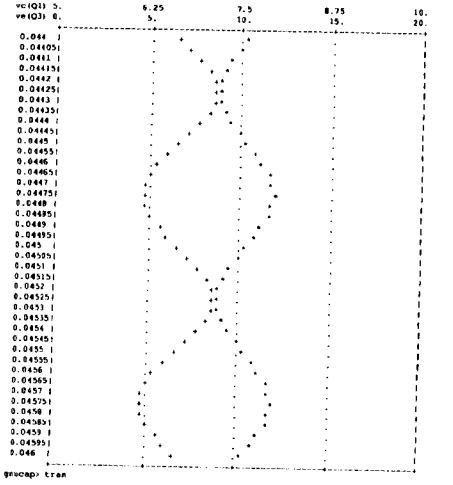

gnucap> tran

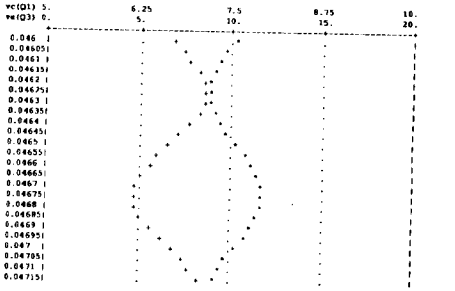

vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran

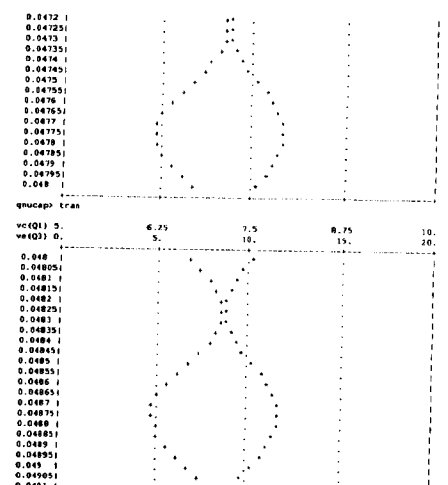

vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran

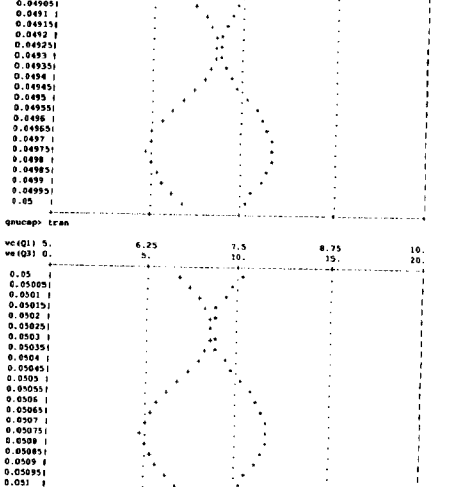

vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.

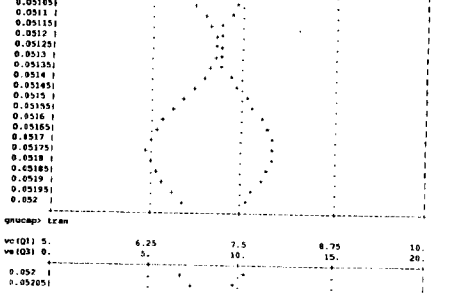

gnucap> tran


vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran


vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.


gnucap> tran


vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.
gnucap> tran


vc(Q1) 5. 6.25 7.5 8.75 10.
ve(Q3) 0. 5. 10. 15. 20.