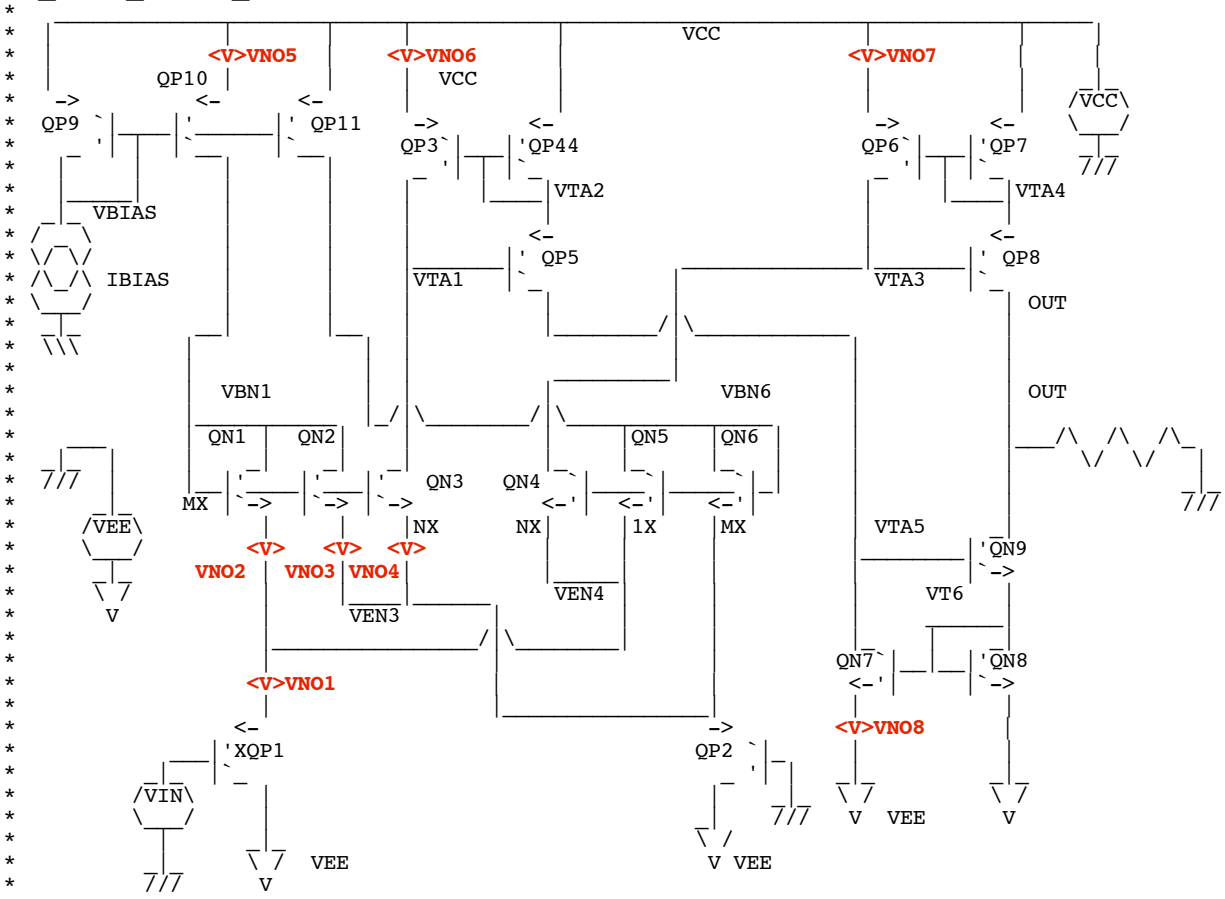
AB_Bias_Audio_OffsetNoise




```
.OPTIONS  GMIN=1e-12    METHOD=trap   srcsteps = 1  gminsteps = 1
.OPTIONS  ITL1=400      ITL2=100      ITL6=100
.OPTIONS  RELTOL=.001   ABSTOL=1p     VNTOL=1u

*======== ====== ====== ====== ====== ====== ====== ====== ======
VCC       VCC    0      DC     2
VEE       0      VEE    DC     2
VIN       VIN    0      DC     0
IBIAS     VBIAS  0      .16u
QP9       VBIAS  VBIAS  VCC    PNP1   1
QP10      VBN1   VBIAS  VCCB   PNP1   1
QP11      VBN6   VBIAS  VCC    PNP1   1
QP1       VEE    VIN    VEN4B  PNP1   1
QP2       VEE    0      VEN3   PNP1   1
QP3       VTA1   VTA2   VCCC   PNP1   1
QP4       VTA2   VTA2   VCC    PNP1   1
QP5       VTA5   VTA1   VTA2   PNP1   1
QP6       VTA3   VTA7   VCCD   PNP1   1
QP7       VTA7   VTA7   VCC    PNP1   1
QP8       OUT    VTA3   VTA7   PNP1   1

QN7       VTA5   VTA6   VEEB   NPN1   1
QN8       VTA6   VTA6   VEE    NPN1   1
QN9       OUT    VTA5   VTA6   NPN1   1

R1        OUT    0      1
QN1       VBN1   VBN1   VEN4C  NPN1   4.5
QN6       VBN6   VBN6   VEN3   NPN1   4.5
QN2       VBN1   VBN1   VEN3B  NPN1   1
QN5       VBN6   VBN6   VEN4   NPN1   1
QN3       VTA1   VBN1   VEN3C  NPN1   15
QN4       VTA3   VBN6   VEN4   NPN1   15

VNO1      VEN4   VEN4B  DC     0
VNO2      VEN4   VEN4C  DC     0
VNO3      VEN3   VEN3B  DC     0
VNO4      VEN3   VEN3C  DC     0
VNO5      VCC    VCCB   DC     0
VNO6      VCC    VCCC   DC     0
```

```
VNO7       VCC     VCCD    DC      0
VNO8       VEE     VEEB    DC      0



.control
setplot new
set thisData =       data
let $thisData =      0 * vector(38)
set thisData2 =      data2
let $thisData2 =     0 * vector(38)

let n=0
repeat 17
let         unknown.{$thisData2}[n] = n
let n=n+1
endrepeat


*==========Geometry_Sensitivity==================
* Add a voltage source in series with one transistor for each matched pair
* measure the effect of adding a standart error (1mV or 1%)
* Store all gain and offset results for each transistor
* Calibrate each transistor to its area and processing expectations


*#0========Define_1X_NPN_and_PNPL_and_RB_Offsett===========
let         npnoff = .6m
let         pnpoff = 1.1m
let         rboff  = .005
let         unknown.{$thisData}[0] = npnoff
let         unknown.{$thisData}[1] = pnpoff
let         unknown.{$thisData}[2] = rboff
let         npnbf = @NPN1[bf]
let         pnpbf = @PNP1[bf]
let         npnrb = @NPN1[rb]
let         pnprb = @PNP1[rb]

echo       "Process Expectations  "
echo       "NPN_offset    =  $&npnoff  "
echo       "NPN_beta      =  $&npnbf  "
echo       "NPN_rbase     =  $&npnrb  "
echo       "PNPL_offset   =  $&pnpoff  "
echo       "PNPL_beta     =  $&pnpbf  "
echo       "PNPL_rbase    =  $&pnprb  "
echo       "Rbase_offset =  $&rboff  "
echo       ""

*#0========Measure_With_No_Errors===========
op
let         unknown.{$thisData}[3] = out
let         ibb     = @ibias[dc]
let         icc     =  -1*vcc#branch
echo       "Ibias         =  $&ibb  "
echo       "Isupply       =  $&icc "
echo       ""

*==========Measure_Offset_Gain_Each_Transitor==================
* Add 1mv offset one at a time to each transistor
* Measure change at output
* Store gain and offset results for each transistor
* measure transistor area
* calculate each transistors offset from area and npnoff, pnpoff, and rboff


*#1========Measure_OTA_gm_At_1mV===========
alter       vin     dc =     1m
op
let         gm =    abs(out- unknown.{$thisData}[3]) /1m
let         unknown.{$thisData}[4] = gm
alter       vin     dc =     0

*#2========Measure_VNO1_effect===========
alter       vno1    dc =     1m
op
let         procOff = unknown.{$thisData}[1]
let         Tarea   = @qp1[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[5] = vingain
```

```
let         unknown.{$thisData}[6] = vinoff
echo       "Pair      ProcOff   Area  Pair_Off  Gain2Vin   Vin_Offset "
echo       "QP1/QP2    $&procOff     $&Tarea      $&pairOff     $&vingain     $&vinoff"

*#3========Measure_VNO2_effect===========
alter       vno1    dc =     0
alter       vno2    dc =     1m
op
let         procOff = unknown.{$thisData}[0]
let         Tarea   = @qn1[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[7] = vingain
let         unknown.{$thisData}[8] = vinoff
echo       "QN1/QN6    $&procOff     $&Tarea      $&pairOff     $&vingain    $&vinoff"

*#4========Measure_VNO3_effect===========
alter       vno2    dc =     0
alter       vno3    dc =     1m
op
let         procOff = unknown.{$thisData}[0]
let         Tarea   = @qn2[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[9] = vingain
let         unknown.{$thisData}[10] = vinoff
echo       "QN2/QN5    $&procOff     $&Tarea      $&pairOff    $&vingain   $&vinoff"

*#5========Measure_VNO4_effect===========
alter       vno3    dc =     0
alter       vno4    dc =     1m
op
let         procOff = unknown.{$thisData}[0]
let         Tarea   = @qn3[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[11] = vingain
let         unknown.{$thisData}[12] = vinoff
echo       "QN3/QN4    $&procOff     $&Tarea      $&pairOff    $&vingain    $&vinoff"

*#6========Measure_VNO5_effect===========
alter       vno4    dc =     0
alter       vno5    dc =     1m
op
let         procOff = unknown.{$thisData}[1]
let         Tarea   = @qp10[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[13] = vingain
let         unknown.{$thisData}[14] = vinoff
echo       "QP10/QP11 $&procOff     $&Tarea      $&pairOff    $&vingain    $&vinoff"

*#7========Measure_VNO6_effect===========
alter       vno5    dc =     0
alter       vno6    dc =     1m
op
let         procOff = unknown.{$thisData}[1]
let         Tarea   = @qp3[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[15] = vingain
let         unknown.{$thisData}[16] = vinoff
echo       "QP3/QP4    $&procOff     $&Tarea      $&pairOff    $&vingain    $&vinoff"

*#8========Measure_VNO7_effect===========
alter       vno6    dc =     0
alter       vno7    dc =     1m
op
let         procOff = unknown.{$thisData}[1]
```

```
let         Tarea   = @qp6[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[17] = vingain
let         unknown.{$thisData}[18] = vinoff
echo       "QP6/QP7   $&procOff    $&Tarea     $&pairOff   $&vingain   $&vinoff"

*#9========Measure_VNO8_effect===========
alter       vno7   dc =    0
alter       vno8   dc =    1m
op
let         procOff = unknown.{$thisData}[0]
let         Tarea   = @qn7[area]
let         Ioutref = unknown.{$thisData}[3]
let         gm      = unknown.{$thisData}[4]
let         vingain  = 1000*(out - Ioutref)/gm
let         pairOff = (1/Tarea)^.5*procOff
let         vinoff  = pairOff*vingain
let         unknown.{$thisData}[19] = vingain
let         unknown.{$thisData}[20] = vinoff
echo       "QN7/QN8   $&procOff    $&Tarea     $&pairOff   $&vingain   $&vinoff"

*#10========Add_Up_total_offset===========
let         off1   = unknown.{$thisData}[6]
let         off2   = unknown.{$thisData}[8]
let         off3   = unknown.{$thisData}[10]
let         off4   = unknown.{$thisData}[12]
let         off5   = unknown.{$thisData}[14]
let         off6   = unknown.{$thisData}[16]
let         off7   = unknown.{$thisData}[18]
let         off8   = unknown.{$thisData}[20]
let         Vin_total =  (off1^2+off2^2+off3^2+off4^2+off5^2+off6^2+off7^2+off8^2 )^.5

echo        " "
echo        "Total referred to input offset   $&Vin_total"
echo        " "

*#8========Measure_Maximum_Iout===========
alter       vno8   dc =    0
alter       vin    dc =    -430m
op
let         unknown.{$thisData}[22] = out
*echo        "Clipping +/- output current          $&out A"

alter       vin   dc =    0
op


*==========Calculating_Noise_Each_Transitor==================
* Find Area and Emitter current for each transistor (Qn)
* Noise Resistance = (kt/q)/(2*Ie) + Rb/area
* Input_noise_Qn = 4.07nV/rtHz*sqrt(Noise Resistance/1000)
* output_noise_Qn = output_noiseQn*Gain_Qn

*#7========Calc_VNO1_effect_On_Noise===========
let         icc     = @qp1[ic]
let         Tarea   = @qp1[area]
let         rbb     = @PNP1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07n*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[5]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[23] = VinNois
echo       "Pair     Ic           NoiseRes  Pair_Noise   Gain2Vin  VnoiseIn_rtHz  OutNoise_rtHz"
echo       "QP1/QP2  $&icc  $&NoiseR   $&NoiseP  $&Gain2in   $&VinNois    $&IoutNo"

*#8========Calc_VNO2_effect_On_Noise===========
let         icc     = @qn1[ic]
let         Tarea   = @qn1[area]
let         rbb     = @NPN1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[7]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[24] = VinNois
echo       "QN1/QN6  $&icc  $&NoiseR   $&NoiseP   $&Gain2in  $&VinNois    $&IoutNo"
```

```
*#9=======Calc_VNO3_effect_On_Noise===========
let         icc     = @qn2[ic]
let         Tarea   = @qn2[area]
let         rbb     = @NPN1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[9]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[25] = VinNois
echo       "QN2/QN5  $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"

*#10=======Calc_VNO4_effect_On_Noise===========
let         icc     = @qn3[ic]
let         Tarea   = @qn3[area]
let         rbb     = @NPN1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[11]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[26] = VinNois
echo       "QN3/QN4  $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"

*#10=======Calc_VNO5_effect_On_Noise===========
let         icc     = @qp10[ic]
let         Tarea   = @qp10[area]
let         rbb     = @PNP1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[13]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[27] = VinNois
echo       "QP10/QP11 $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"

*#10=======Calc_VNO6_effect_On_Noise===========
let         icc     = @qp3[ic]
let         Tarea   = @qp3[area]
let         rbb     = @PNP1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[15]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[28] = VinNois
echo       "QP3/QP4  $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"

*#10=======Calc_VNO7_effect_On_Noise===========
let         icc     = @qp6[ic]
let         Tarea   = @qp6[area]
let         rbb     = @PNP1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[17]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[29] = VinNois
echo       "QP6/QP7  $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"


*#10=======Calc_VNO8_effect_On_Noise===========
let         icc     = @qn7[ic]
let         Tarea   = @qn7[area]
let         rbb     = @PNP1[rb]/Tarea
let         NoiseR  = rbb + 13m/icc
let         NoiseP  = 4.07e-9*(2*NoiseR/1000)^.5
let         Gain2in = unknown.{$thisData}[19]
let         VinNois = abs(NoiseP*Gain2in)
let         gm      = unknown.{$thisData}[4]
let         IoutNo  = VinNois*gm
let         unknown.{$thisData}[30] = VinNois
echo       "QN7/QN8  $&icc  $&NoiseR   $&NoiseP $&Gain2in  $&VinNois    $&IoutNo"


*#11=======Add_Up_All_Noise===========

let         off1    = unknown.{$thisData}[23]
let         off2    = unknown.{$thisData}[24]
```

```
let        off3   = unknown.{$thisData}[25]
let        off4   = unknown.{$thisData}[26]
let        off5   = unknown.{$thisData}[27]
let        off6   = unknown.{$thisData}[28]
let        off7   = unknown.{$thisData}[29]
let        off8   = unknown.{$thisData}[30]
let        Vin_T  =  (off1^2+off2^2+off3^2+off4^2+off5^2+off6^2+off7^2+off8^2 )^.5
let        Out_T  = Vin_T*gm
let        ibb    = @ibias[dc]
let        ibb    = unknown.{$thisData}[22]
let        SigNo  = 20*log(ibb/(Out_T*141)) -3

let        Rgm    = 1/unknown.{$thisData}[4]
let        Vin_max = ibb*Rgm


echo       " "
echo       "Rgm  (vin/iout)                        $&Rgm Ohms"
echo       "Total referred to input noise_rtHz     $&Vin_T V"
echo       "Vin maxium                             $&Vin_max V"
echo       "Total output current noise_rtHz        $&Out_T A"
echo       "Clipping +/- output current            $&ibb A"
echo       "Clipping 20-20KHz output S/N           $&SigNo dB"

echo       " "



.endc

*======== models Using Near Perfect Transistors ==================
.model     NPN1    NPN(    BF =    200     VAF =   100     rb=400 )
.model     PNP1    PNP(    BF =    30      VAF =   150     rb=900 )
*======== ====== ====== ====== ====== ====== ====== ====== ======

.end

======================END_OF_SPICE=======================
```

To Covert PDF to plain text click below
http://www.fileformat.info/convert/doc/pdf2txt.htm

Circuit: AB_Bias_Audio_OffsetNoise

```
Process          Expectations
NPN_offset    =  0.0006
NPN_beta      =  200
NPN_rbase     =  400
PNPL_offset   =  0.0011
PNPL_beta     =  30
PNPL_rbase    =  900
Rbase_offset  =  0.005

Ibias         =  1.6E-07
Isupply       =  2.00566E-06

Pair       ProcOff    Area   Pair_Off   Gain2Vin    Vin_Offset
QP1/QP2    0.0011     1      0.0011     -1.00016    -0.00110018
QN1/QN6    0.0006     4.5    0.00028     0.490909    0.00013885
QN2/QN5    0.0006     1      0.0006      0.210912    0.000126547
QN3/QN4    0.0006     15     0.000154   -0.71612    -0.000110941
QP10/QP11  0.0011     1      0.0011      0.872016    0.000959218
QP3/QP4    0.0011     1      0.0011     -1.38178    -0.00151996
QP6/QP7    0.0011     1      0.0011      1.38921     0.00152813
QN7/QN8    0.0006     1      0.0006      1.40827     0.000844963

Total referred to input offset   0.00274545

Pair       Ic           NoiseRes   Pair_Noise    Gain2Vin   VnoiseIn_rtHz   OutNoise_rtHz
QP1/QP2    5.18398E-07  25977.3    2.93363E-08   -1.00016    2.93412E-08     3.01488E-13
QN1/QN6    1.17124E-07  111083     6.06642E-08    0.490909   2.97806E-08     3.06002E-13
QN2/QN5    2.60279E-08  499865     1.28687E-07    0.210912   2.71417E-08     2.78887E-13
QN3/QN4    3.89535E-07  33399.8    3.32645E-08   -0.71612    2.38214E-08     2.4477E-13
QP10/QP11  1.4582E-07   90051.3    5.46203E-08    0.872016   4.76298E-08     4.89407E-13
QP3/QP4    3.76745E-07  35406.1    3.42491E-08   -1.38178    4.73247E-08     4.86272E-13
QP6/QP7    3.76675E-07  35412.5    3.42521E-08    1.38921    4.75833E-08     4.88929E-13
QN7/QN8    3.85655E-07  34608.9    3.38613E-08    1.40827    4.76858E-08     4.89983E-13

Rgm  (vin/iout)                      97321.4 Ohms
Total referred to input noise_rtHz   1.09992E-07 V
Vin maxium                           0.196217 V
Total output current noise_rtHz      1.13019E-12 A
```

Clipping +/- output current 2.01617E-06 A
Clipping 20-20KHz output S/N 79.0431 dB

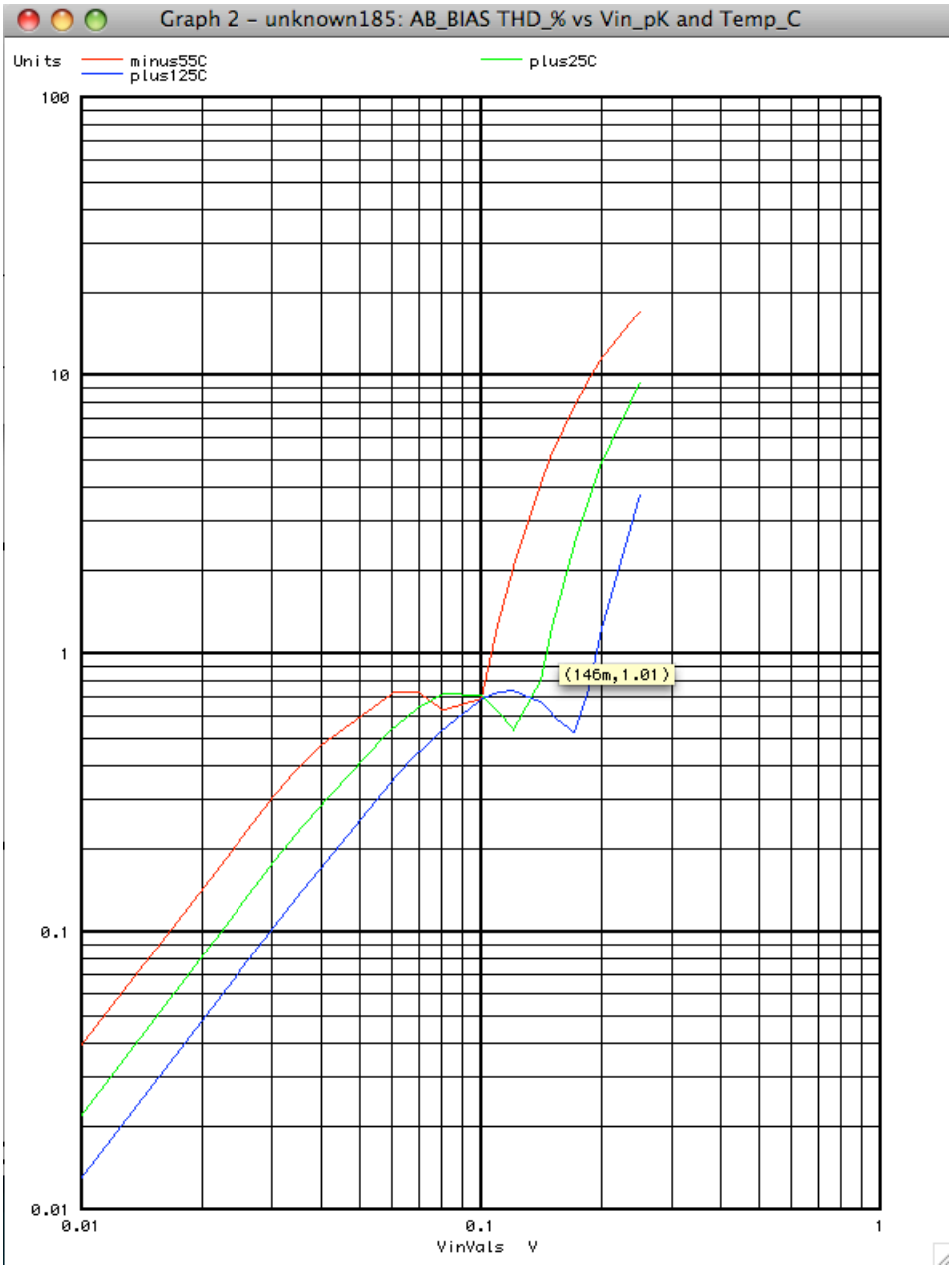
==========AB_Bias_Input_Comparision==========

Since the signal to noise ratio is supply current dependent, the comparison needs to be made at a common 2uA supply current level. This simulation allows the introduction of expected process parameters such as base resistance, beta, and offset. Spice's "alter" feature is used to find individually the contributions of each and every matched pair to the over all performance.

The comparing the AB_Bias Input OTA to a LM3080 Input OTA

	AB_BIAS	LM3080
1) measure supply current	= 2.045uA	2.0uA
2) Measure Max output current	= +/- **2.016uA_pk**	+/- **.97uA_pk**
3) Measure Max Vin extrapolate	= +/- 196mV_pk	+/- 51mV_pk
4) Measure Offset_V	= +/- **2.7mV_sd**	+/- **1.6mV_sd**
5) Measure Offset_Iout_%Imax	= +/- **1.36_%**	+/- **3.2_%**
6) Measure input noise_rtHz	= +/- **110nV_rms**	+/- **56nV_rms**
7) Measure 1% THD output current	= +/- 1.50uA_pk	+/- .334uA_pk
8) Measure 1% THD input V	= +/- **146mV_pk**	+/- **18mV_pk**
9) Meaured Rgm = Vin/Iout	= 97KOhms	51KOhms
10) Total Output Shot Noise	= 159pA_rms	151pA_rms
11) Signal to Noise Clipping	= **79.0dB**	**73dB**
12) Signal to Noise 1% THD	= **76.4dB**	63.5dB

The maximum output current of the AB_bias circuit is twice that of the normal input stage. Since there are a lot more transistors in the AB_Bias input stage, both the referred-to input noise and offset will have to increase. But since the AB_Bias stage can handle much higher signal levels, there is about a factor of two improvement in both offset and noise when operating at the 100% signal levels. With distortion an issue, the AB_Bias input can run at about 75% at a 1% distortion. The Dual differential input will be at the 62% level. A non pre-distorted LM3080 is at a 35% level. In theory a perfect pre-distortion stage can take a LM3080 up to a 100% level. But even when the supply current of a perfect pre-distortion stage is high enough so that it will not effect the signal to noise ratio, the signal to noise ratio will still be 3dB lower than for the AB_Bias Input stage.


Graph 2 – unknown185: AB_BIAS THD_% vs Vin_pK and Temp_C
Units
minus55C
plus125C
plus25C
100
10
1
0.1
0.01
0.01
0.1
1
VinVals V
(146m,1.01)