ECE 425 Project

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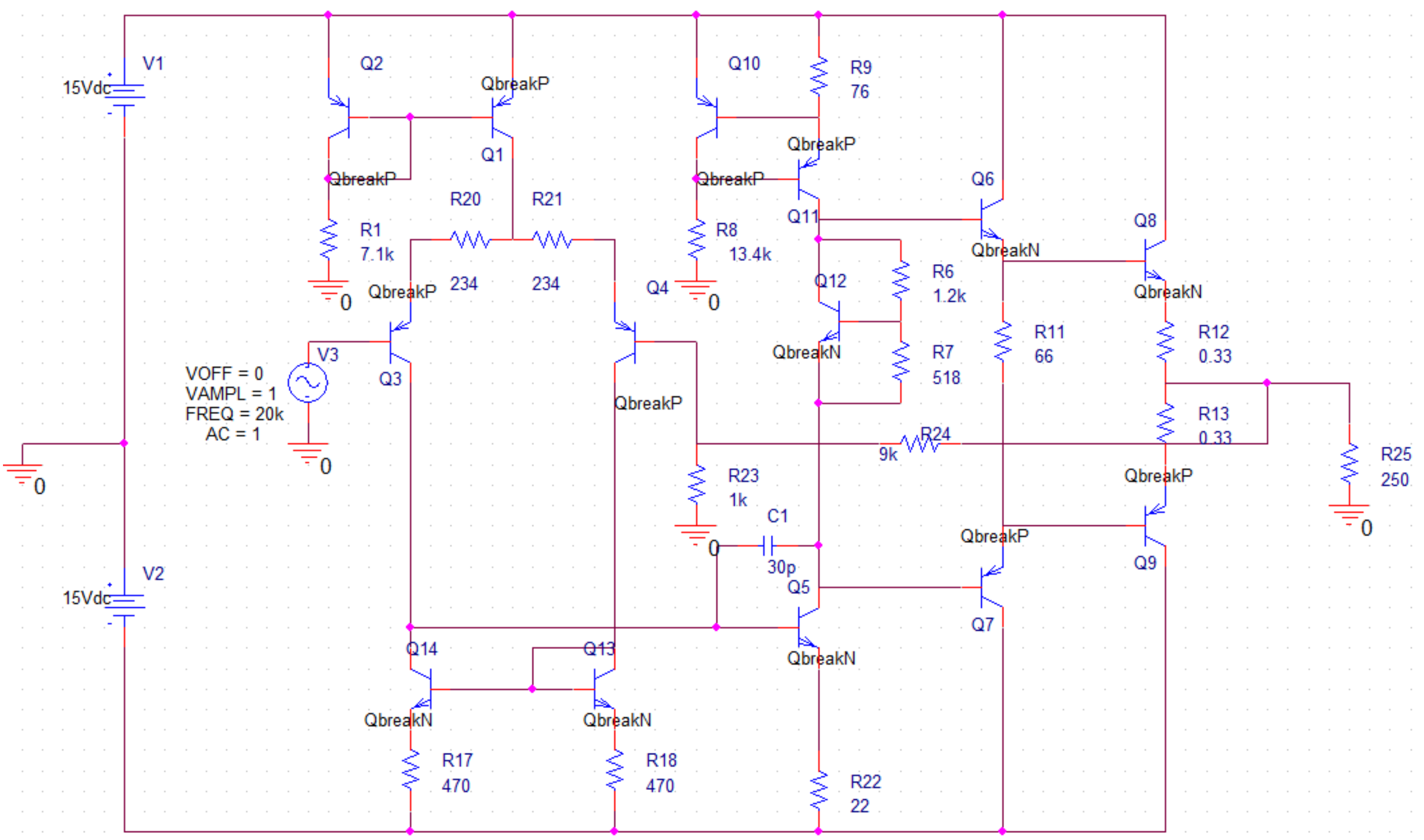
1. Final Schematic, Labels and Parameter definition:



Sketch and analysis using OrCAD Capture CIS Lite and Pspice.

There are few points that have to be clarified first:

1. 250 Ohm is a normal resistance value for a high quality monitor level headphone.
2. The parameters of the voltage source at the input point are not certain values, may be changed during analysis.

More details will be given in part 2.

2. Schematic Detail

1) Circuit summary:

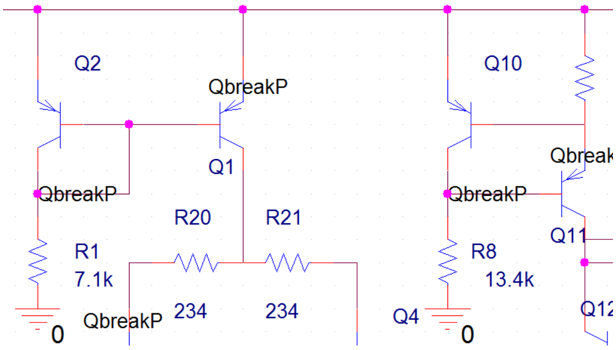
This is an IC schematic of an audio amplifier, which has to meet the demands below:

a) Input signal feature: The input port is always the line out port of an audio player, with the maximum input voltage at about 1V practically.

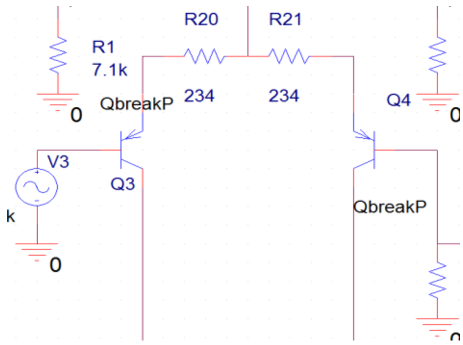
b) Frequency: As it is a sound signal that is always been transferred in this circuit, and the frequency of a sound signal is around the range from 20Hz to 20kHz, the bandwidth demand should be 20-20KHz for sound signal.

c) Output feature: This is a headphone amplifier so the load should be a headphone. The usual headphone impedance value is around 40 Ohm, but these headphones can still be used without an amplifier. Actually, the load of an amplifier is about 200 Ohm and the output power should approach 300mW approximately. In this design, take a 250 load as an example. (All these values are practical and get from internet)

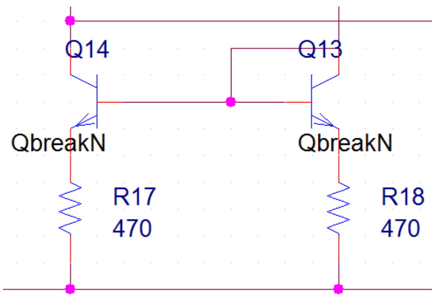
2) Sub-circuit describes:

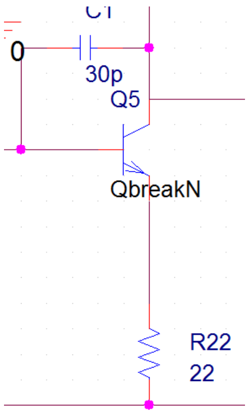


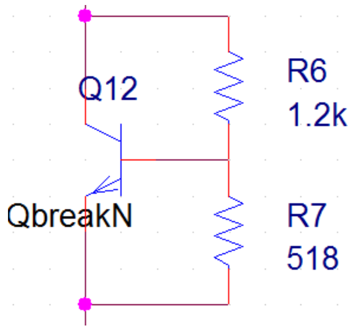
(a)

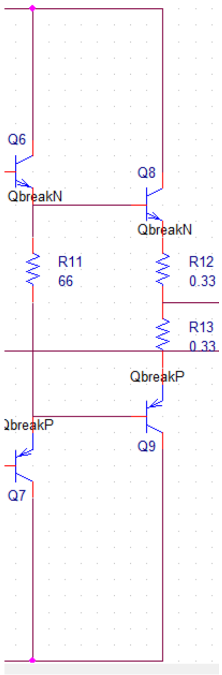


(b)

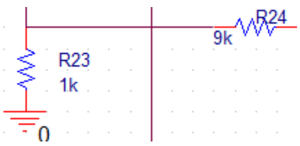








(c) (d) (e) (f)



(g)

a) Current source:

There are two current sources in this design, as it is shown above. This first one is a normal current mirror current source, which provides a stable 2mA current. The second one is a feedback current source which provides a 10mA current.

b) Differential input stage:

This differential structure provides more signal stability by preventing constant noise that affects both two input ports. In this design, two degeneration transistors (R20, R21) are involved to reduce harmonic distortion that caused by the non-linear feature in the input stage.

c) Active load:

Active load is use to increase voltage gain without increasing the load resistance.

d) Common-emitter stage:

Provide large voltage gain. C1 is used to stabilize the circuit at high frequency condition.

e) Voltage multiplier:

Provide stable voltage bias by multiple Vbe, which is less likely to change. This is used to form a AB output stage, in which it prevents the distortion at zero point in traditional B type amplifier.

f) Output stage:

A two stage output part is involved in this design, which provides a very large output resistance for common-emitter stage to guarantee a very large voltage gain in this stage. The gain of this stage is around one, because it performs a role like a voltage buffer that makes the output more stable and linear and guarantees enough power for the load. Three emitter resistors are also involved to prevent immediate large current flow through and break transistors.

g) Feedback:

It performs a 10/1 negative feedback, because in order to get the output power we want, the maximum output voltage should be 10v. Since the gain of this amplifier is very large, we can set the feedback as above to get the gain we want.

3. Schematic specification

a) Power dissipation

The power dissipation can be get from the .out report file when running timing simulation with grounded input. As it is shown below:

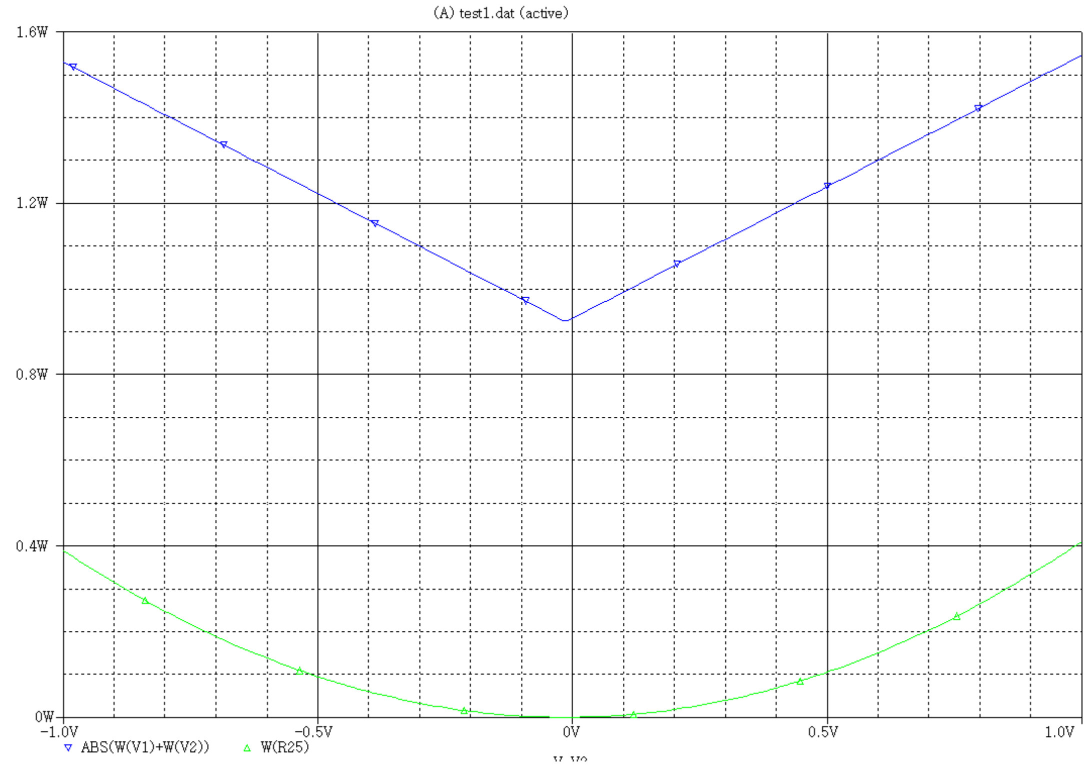
```
VOLTAGE SOURCE CURRENTS
NAME           CURRENT

V_V1          -3.283E-02
V_V2          -2.927E-02

TOTAL POWER DISSIPATION   9.31E-01  WATTS
```

b) Power consumption

The total power consumption can be calculated from the power of the two supply voltage sources when running a DC analysis. It is shown on the figure below that the maximum power consumption appears when the input is 1V or -1V.



We can build a measurement on this waveform. As it is shown below, the least power consumption, maximum power consumption and the maximum supply power are measured.

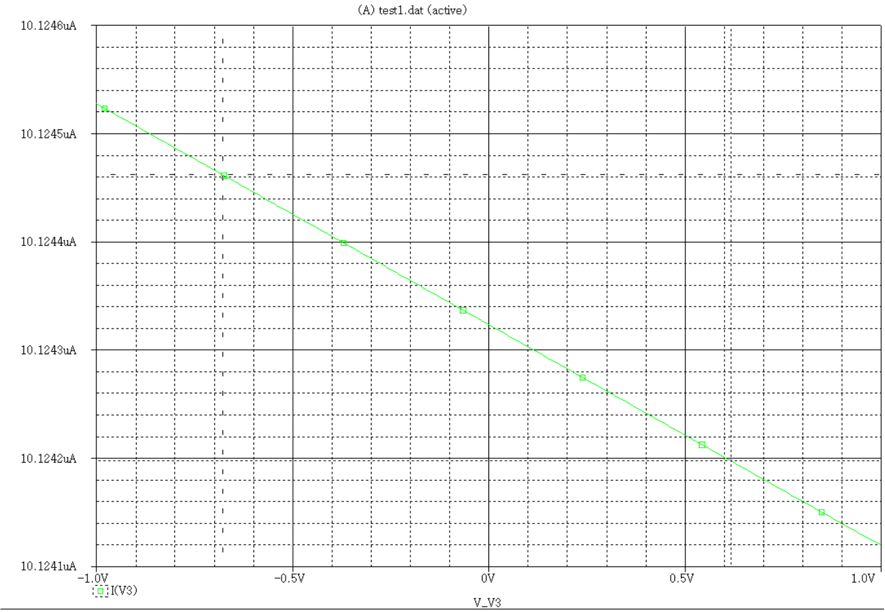
Measurement Results				
	Evaluate	Measurement	Value	
	☑	Min(ABS(W(V1)+W(V2)))	925.34416m	
	☑	Max(ABS(W(V1)+W(V2)))	1.54607	
▶	☑	Max(ABS(W(V1)))+Max(ABS(W(V2)))	2.15299	

So the maximum power consumption is about 1.55W. Note that the minimum consumption value (925mW) is not the same but very close with the power dissipation as zero input.

c) Supply power requirement:

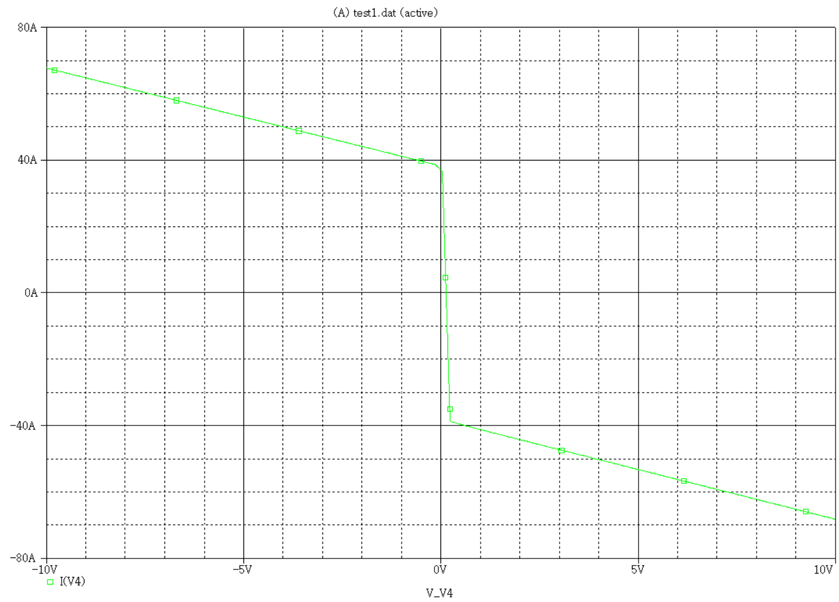
The supply power of the two voltage sources should be larger than the maximum supply power in measurement above. Specifically, it is approximately 2.15W.

d) Input characteristic



It is obvious that the input impedance is very large from this waveform, which is around 150k Ohm. This waveform can be get when load resistance is 250 Ohm.

e) Output characteristic



This is the output characteristic when the input is set to zero and the load is replaced by a DC voltage source with the voltage sweep from -10V to 10V. Approximately, the output impedance is about 0.1 Ohm.

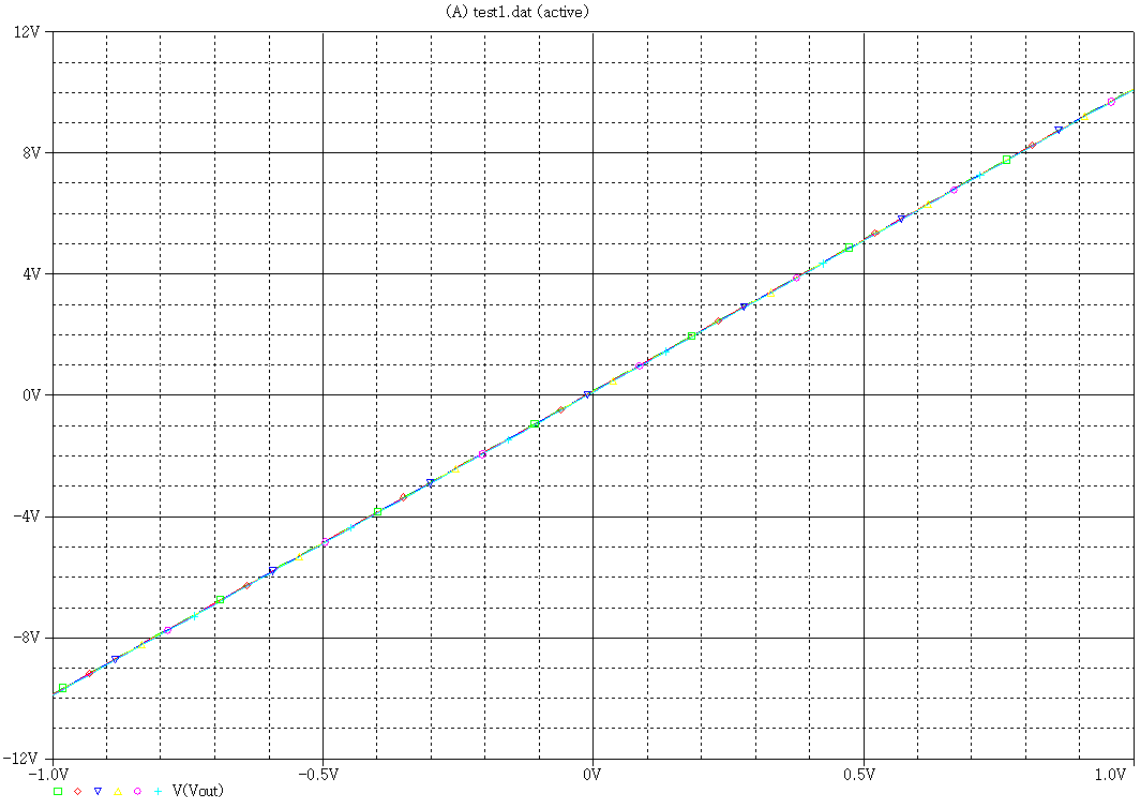
4. Performance

a) DC operation point with temperature from 0 ^{o}C to 100^{o}C.

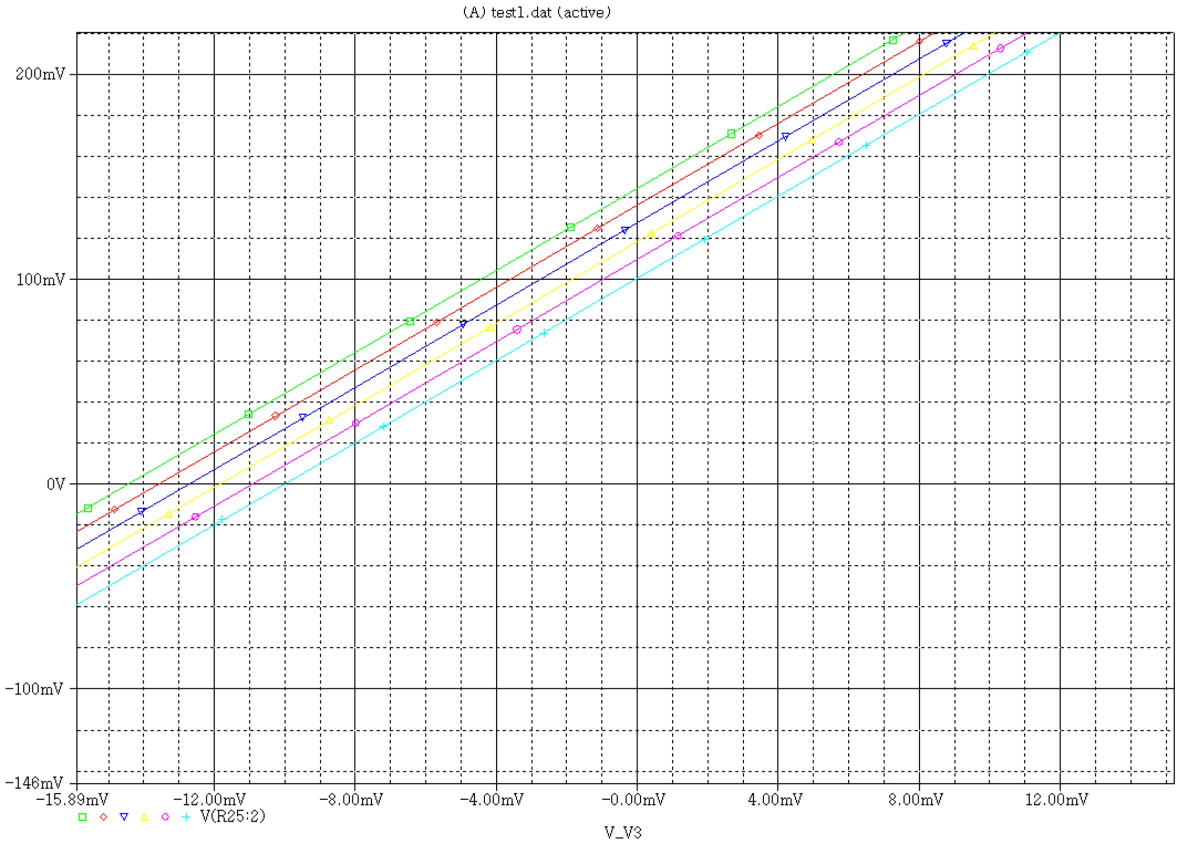
The following waveform shows the DC characteristics of this amplifier. It is clear that the output is linear with the voltage about ten times the input voltage. The temperature issue is also included in this form, in which:

□ ◇ ▽ △ ○ + V(Vout)

It stands for the waveforms under temperatures of 0, 20, 40, 60, 80 and 100 ^{o}C respectively. This stay the same for all the temperature analysis below.



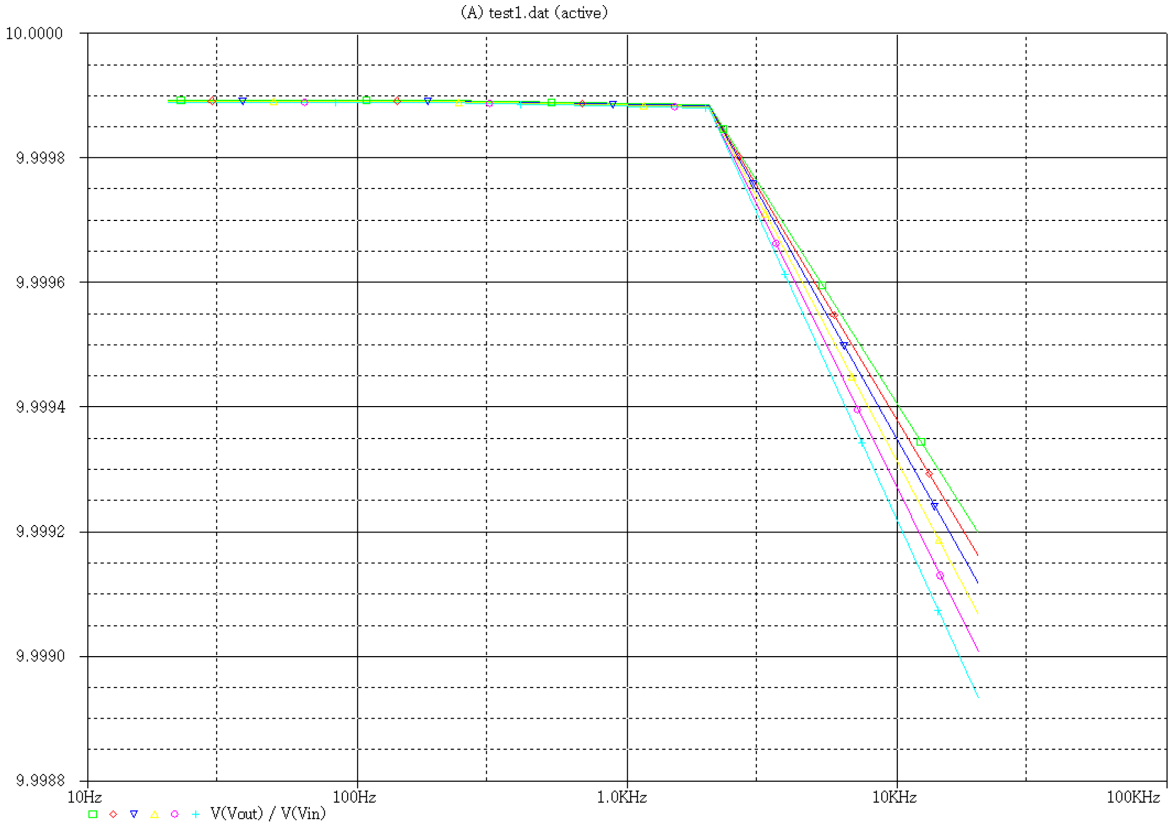
To make it clear, zoom into the area around zero point and get the waveform below:



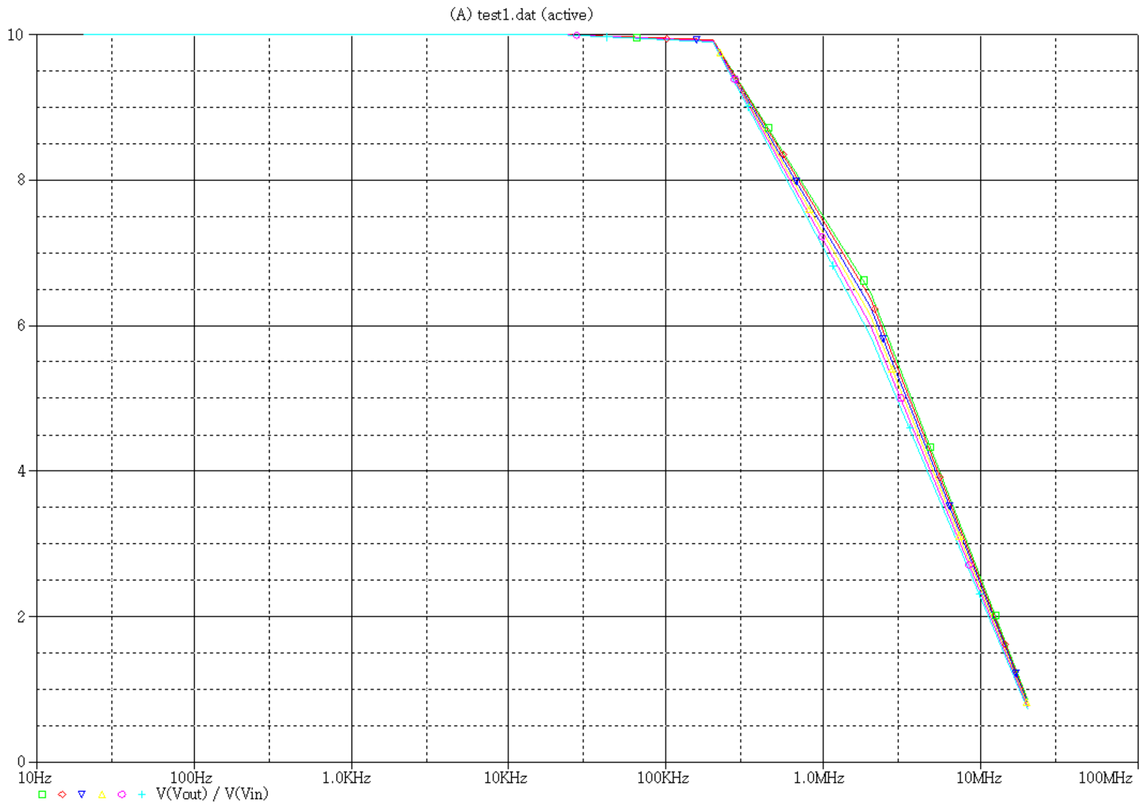
It shows that the higher temperature bring more accurate zero operation point. However, the bias is already small in all temperature cases.

b) AC response with changing temperature.

The following waveform gives the voltage gain change along with the frequency from 0-20kHz. It is clear that the gain under higher temperature drops faster, though the drop value is very small and can be ignored even under 20kHz



The waveform below provides the gain result with the frequency range from 0 to 20M Hz. It can be seen that the high temperature do narrow the bandwidth. However, the bandwidth is still much larger than 20kHz, so it still meets our demand very well.



c) Total harmonic distortion

The total harmonic distortion is a very important value to evaluate the quality of an audio amplifier. In this design, I did the distortion analysis under 1 kHz and 20 kHz respectively.

1 kHz distortion report:

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(R_R25)

DC COMPONENT = -2.040201E-01

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	1.000E+03	9.526E+00	1.000E+00	-1.792E+02	0.000E+00
2	2.000E+03	1.530E-01	1.606E-02	-1.060E+02	2.523E+02
3	3.000E+03	1.392E-01	1.461E-02	-1.114E+02	4.261E+02
4	4.000E+03	1.259E-01	1.321E-02	-1.227E+02	5.939E+02
5	5.000E+03	1.269E-01	1.332E-02	-1.333E+02	7.624E+02
6	6.000E+03	1.252E-01	1.314E-02	-1.366E+02	9.383E+02
7	7.000E+03	2.289E-01	2.403E-02	1.649E+02	1.419E+03
8	8.000E+03	8.776E-02	9.213E-03	-1.426E+02	1.291E+03
9	9.000E+03	1.168E-01	1.226E-02	-7.973E+01	1.533E+03
10	1.000E+04	6.439E-02	6.760E-03	-1.593E+02	1.632E+03
11	1.100E+04	5.840E-02	6.130E-03	-1.606E+02	1.810E+03
12	1.200E+04	5.101E-02	5.355E-03	-1.569E+02	1.993E+03
13	1.300E+04	4.151E-02	4.358E-03	-1.509E+02	2.178E+03
14	1.400E+04	3.297E-02	3.461E-03	-1.465E+02	2.362E+03
15	1.500E+04	6.197E-02	6.506E-03	-1.120E+02	2.575E+03
16	1.600E+04	3.184E-02	3.342E-03	-1.478E+02	2.719E+03
17	1.700E+04	3.157E-02	3.314E-03	1.592E+02	3.205E+03
18	1.800E+04	3.615E-02	3.795E-03	-1.368E+02	3.088E+03
19	1.900E+04	3.369E-02	3.537E-03	-1.340E+02	3.270E+03
20	2.000E+04	3.116E-02	3.271E-03	-1.348E+02	3.448E+03

TOTAL HARMONIC DISTORTION = 4.531657E+00 PERCENT

20 kHz distortion report:

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(R_R25)

DC COMPONENT = -2.607866E-01

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	2.000E+04	9.565E+00	1.000E+00	-1.791E+02	0.000E+00
2	4.000E+04	2.834E-01	2.963E-02	-1.111E+02	2.470E+02
3	6.000E+04	2.440E-01	2.551E-02	-1.165E+02	4.207E+02
4	8.000E+04	2.080E-01	2.174E-02	-1.294E+02	5.868E+02
5	1.000E+05	2.046E-01	2.139E-02	-1.481E+02	7.472E+02
6	1.200E+05	2.064E-01	2.157E-02	-1.534E+02	9.210E+02
7	1.400E+05	1.589E-01	1.662E-02	1.392E+02	1.393E+03
8	1.600E+05	1.351E-01	1.412E-02	-1.504E+02	1.282E+03
9	1.800E+05	1.912E-01	1.998E-02	-1.254E+02	1.486E+03
10	2.000E+05	7.216E-02	7.543E-03	-1.602E+02	1.630E+03
11	2.200E+05	6.616E-02	6.917E-03	-1.622E+02	1.807E+03
12	2.400E+05	6.707E-02	7.012E-03	-1.561E+02	1.993E+03
13	2.600E+05	7.085E-02	7.406E-03	-1.449E+02	2.183E+03
14	2.800E+05	6.920E-02	7.235E-03	-1.345E+02	2.372E+03
15	3.000E+05	8.238E-02	8.612E-03	-1.596E+02	2.526E+03
16	3.200E+05	5.044E-02	5.273E-03	-1.370E+02	2.728E+03
17	3.400E+05	4.096E-02	4.282E-03	-1.070E+02	2.937E+03
18	3.600E+05	5.118E-02	5.350E-03	-1.529E+02	3.070E+03
19	3.800E+05	5.134E-02	5.368E-03	-1.485E+02	3.254E+03
20	4.000E+05	4.758E-02	4.974E-03	-1.416E+02	3.440E+03

TOTAL HARMONIC DISTORTION = 6.528703E+00 PERCENT

As a result, the total harmonic distortion result can be summarized below:

1-THD: 4.53%

20-THD: 6.52%

These values are still too large for a practical audio amplifier, which means some improvements are still needed for this design.

5. Conclusion

In this design, a total design and analysis has been done. However, further jobs are still needed to improve the performance.