AAP572 Microphone Amplifier Testing

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SUMMARY

This is a collection of information to guide the customer in understanding some testing issues and results with the AAP572 chip from ASIC Advantage Incorporated (AAI). This note can be used as a quick introduction to testing of electret microphone amplifier chips in general.

REFERENCE

1. AAL572 Datasheet (available from www.asicadvantage.com)
2. AAL572 Evaluation Board Booklet (contact AAI Marketing for a soft copy)

OVERVIEW

Electret microphones are very widely used in cellphones and other audio applications in a worldwide volume of around one billion per year. They are the electrical equivalent to a classic permanent magnet speaker. The speaker has a magnetic bias applied against a coil inductance. The electrets mic has a permanent voltage bias applied to a foil capacitance. The mic is therefore very high impedance, and needs amplification and a lower impedance to drive other circuits. The typical voltage generated is in the 10mV range. The amplifiers are run with supply voltages around 3 volts and supply currents around 300 microamps.

BASIC SCHEMATIC

Below (Figure 1) is a schematic for a typical application. The microphone is equivalent to an AC signal source through a capacitor (the 5pF capacitor is a simulation model, not an actual discrete device). The amplifier has a DC power provided through a shunt regulator connected to the OUT pin. The OUT pin is AC coupled to the actual output port, here shown with a 100k resistive load. The amp has a feedback capacitor connected to set the gain and frequency response. The AAL572 has an internal shunt regulator set to 1.4 volts DC. With the shown values, the DC current consumption is (2v – 1.4v)/2.2k = 272 microamps. Note that the input is biased internally, and accepts the AC signal from the microphone directly.

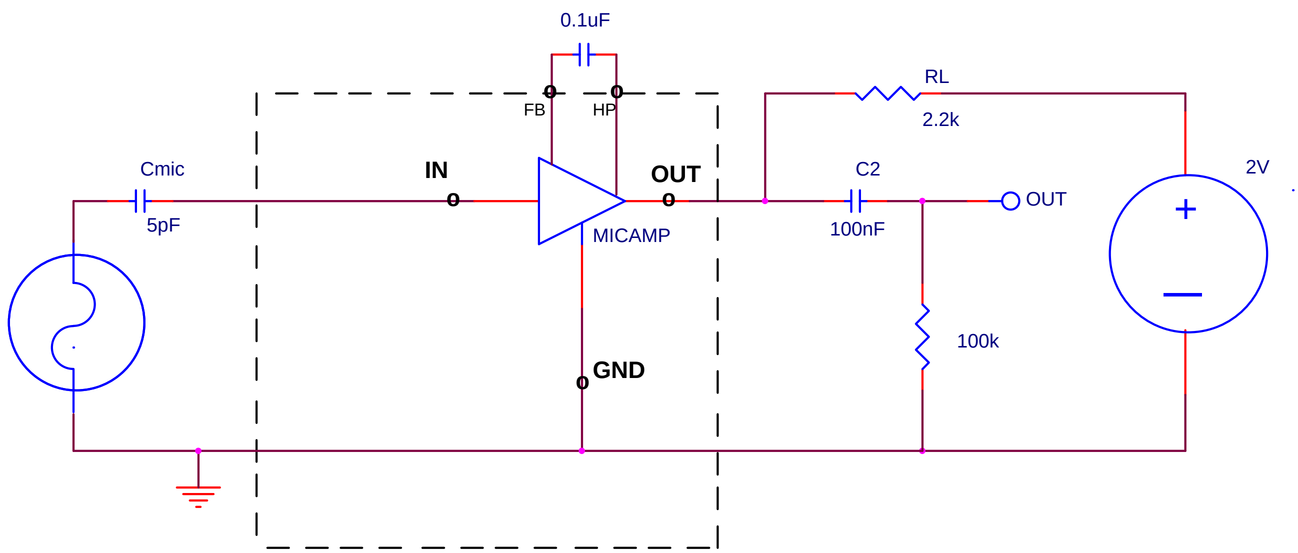

FIGURE 1

FREQUENCY RESPONSE

One the most important specifications is frequency response. Shown below (Figure 2) is a result for the AAL572 obtained using a network analyzer (or dynamic signal analyzer, HP35660A). The vertical scale is 0.5db per division, with a logarithmic horizontal frequency scale going from 128Hz to 51.2 kHz. The shows that the -1dB response is about 300Hz to 51kHz. To get results like this, a few items should be noted:

- The specifications for the amplifier are for a maximum output swing of 250 millivolts peak-to-peak. The midband peak gain is 14.5 dB (a voltage gain of 10**[14.5/20] = 5.3). This means the allowed maximum input swing is 250/5.3 = 47 millivolts peak-to-peak (or, 47/2 = 23 millivolts peak maximum, or 23/1.414 = 16 millivolts rms maximum). This data was taken with 10 millivolts rms input.
- The setup here used 2.2 volts DC input and a 3.3k output resistor
- This 1980's vintage analyzer has a maximum frequency of 51kHz in network analyzer mode (two input channels and a tracking oscillator source).
- There is no windowing applied (otherwise known as "uniform").
- To reduce the amount of displayed noise, this is an average of 50 measurements.
- Please ignore the red dot in the pictures caused by the camera autofocus function.

Figure 3 shows the low frequency response. The vertical scale is 2dB per division and the displayed frequency range is 32Hz to 12.8kHz. The -3dB frequency from midband is around 150 Hz.

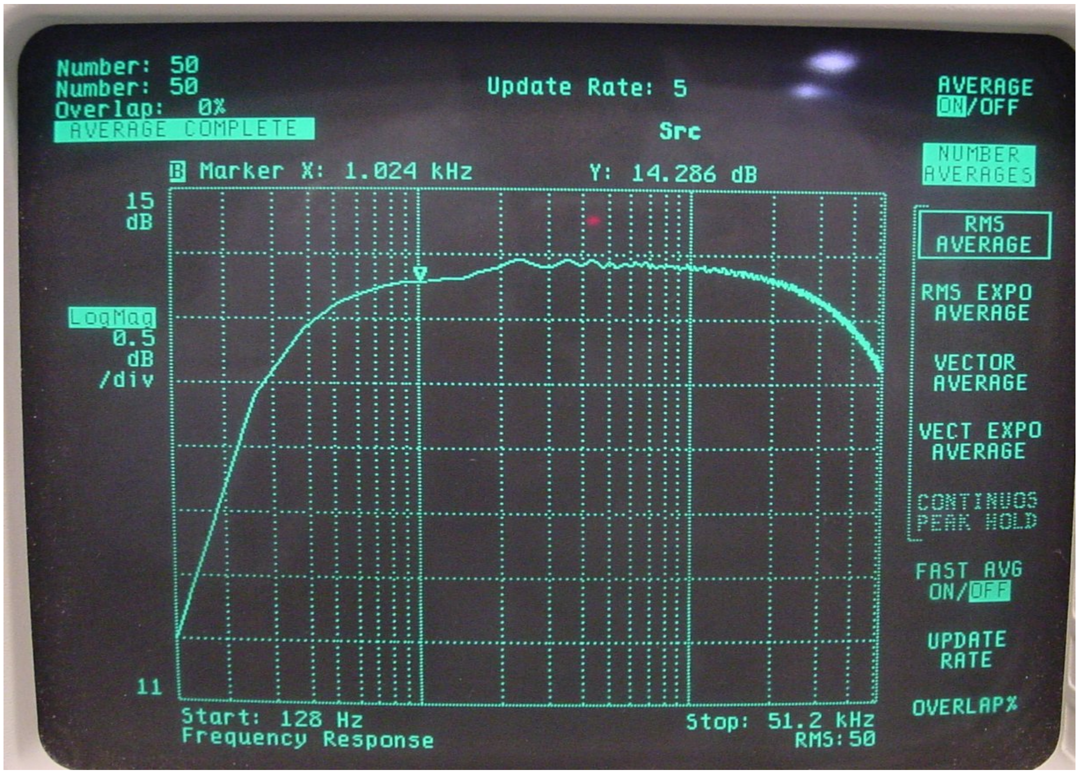

FIGURE 2

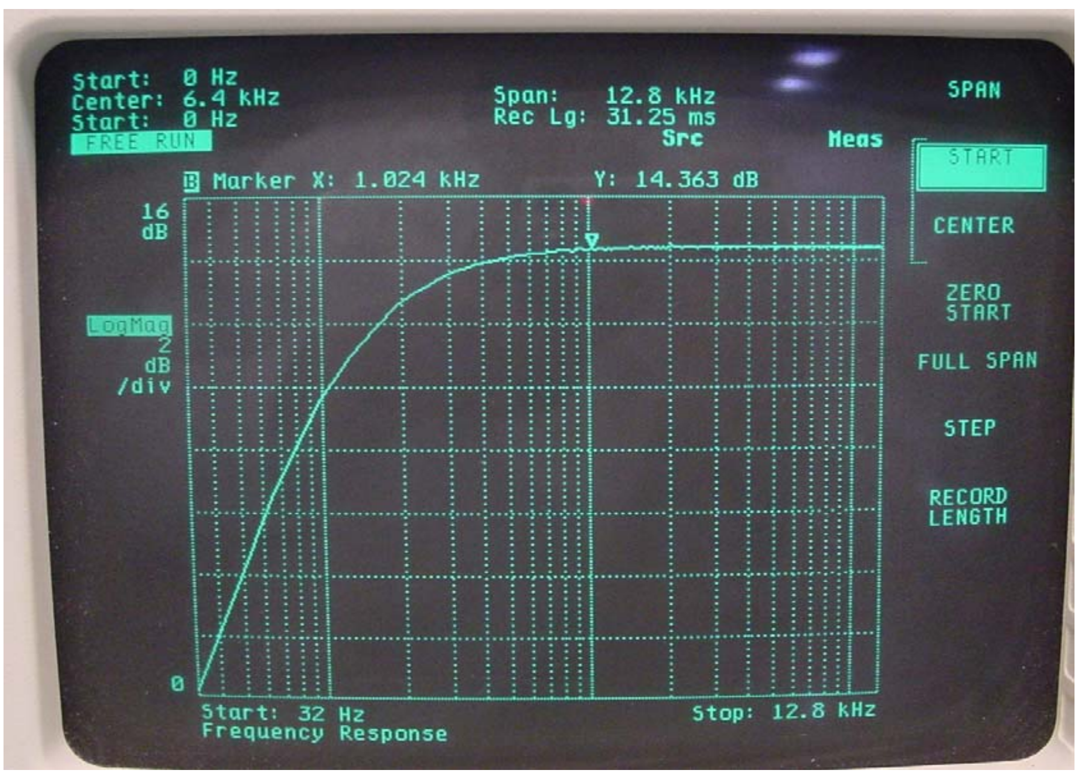

FIGURE 3

NOISE MEASUREMENT

The noise from the AAP572 is below the ability of the analyzer used above to measure. A spectrum analyzer (no signal source, only one input channel needed, Stanford Research Systems SR760) was therefore used. The input was shorted and the output noise was measured, as shown below in Figure 4. The vertical scale is 5 dB per division (with the top being -70dB). This has linear frequency scale going from 0 Hz to 100 kHz (10kHz per division). The marker shows a datapoint of -97 dBrms at 34 kHz. A few items to note are:

- This is a flat measurement. For many audio applications, an A-weighting of the noise spectrum is applied to try to more closely mimic the response of the human ear. That wasn't done here. A-weighting isn't defined above 16kHz anyways.
- The low frequency bumps at 60/120/180/240 Hz are due to power line frequency noise in the lab (fluorescent light ballasts, etc). The high frequency humps are likely from other lab equipment as well. A shielded room is suggested, as well as battery operation.

Figure 5 shows a view of the low frequency part of the spectrum (about 39 Hz per division horizontal, 10 dB per division vertical, marker shows -104 dBVrms at 136 Hz). The power line harmonics are clearly visible

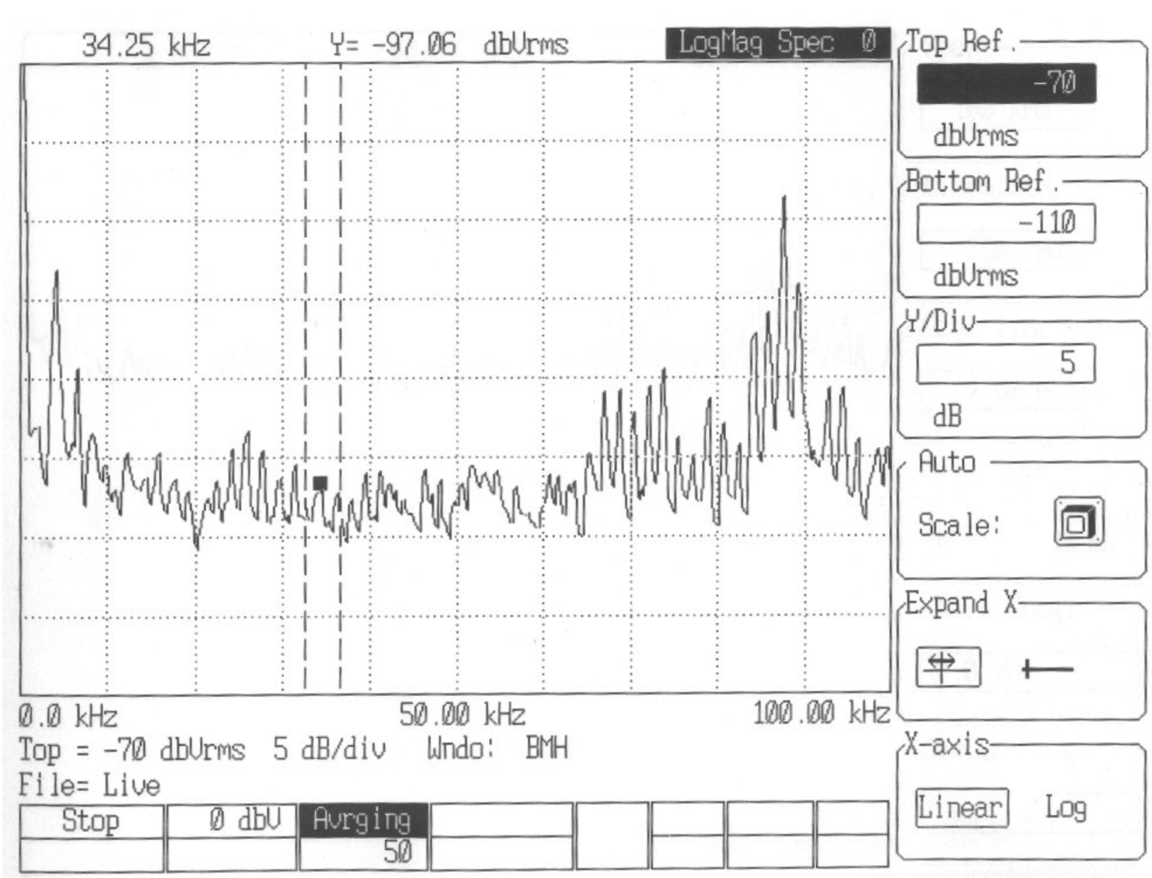

FIGURE 4

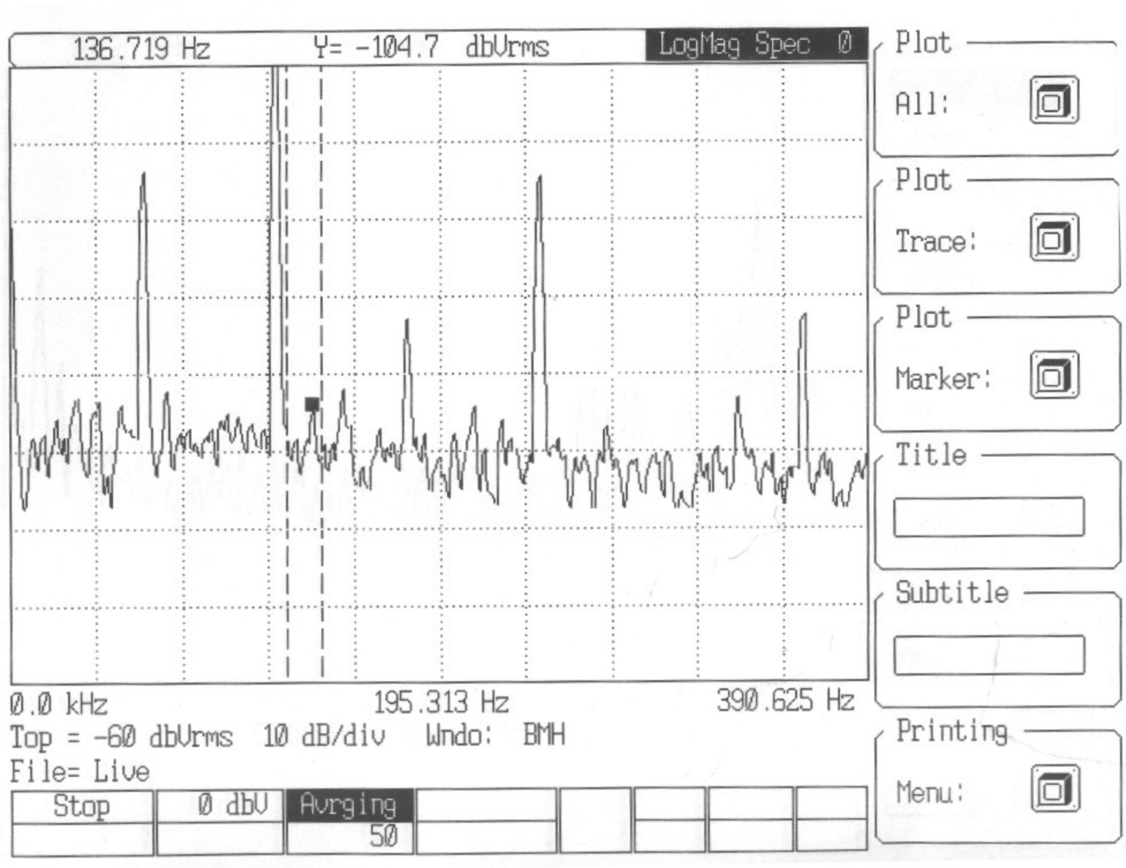

FIGURE 5

DISTORTION MEASUREMENT

The distortion of audio signals is typically derived from taking a (pure) sine wave, applying it to the input, measuring it and all the harmonics of the sine waves frequency, and adding them up as Total Harmonic Distortion (THD):

$$\mathrm{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$$

FIGURE 6

In the above V1 is the amplitude of the fundamental, V2 is the amplitude of the first harmonic (at twice the frequency of the fundamental), etc. So, it is a square root of the the sum-of-squares divided by the fundamental. 100 times this is the percentage. Or, 20 log this is expressed in dB. We will use the same SR760 spectrum analyzer for this (along with Excel, for the math, using the marker in the analyzer to pick the frequencies and amplitudes of choice). In Excel, I labeled the fundamental as F0 (sorry for the confusion).

An example calculation using a 1kHz signal generator directly connected to the analyzer (no amplifier) gives (F8 was so low that it was in-the-noise, and was assigned an arbitrarily small value of -150dB):

Direct Signal Generator Connection				
Harmonic	dB	amplitude	Squared	
F0	-20	0.1		
F2	-104	6.30957E-06	3.98107E-11	
F3	-94	1.99526E-05	3.98107E-10	
F4	-107	4.46684E-06	1.99526E-11	
F5	-101	8.91251E-06	7.94328E-11	
F6	-112	2.51189E-06	6.30957E-12	
F7	-105	5.62341E-06	3.16228E-11	
F8	-150	3.16228E-08	1E-15	
F9	-103	7.07946E-06	5.01187E-11	
			6.25355E-10	Sumsqur
			2.50071E-05	sqrtsumsqur
			0.025007107	%
			-72.0387309	dB

FIGURE 7

This says that with this setup, we can't measure below 0.025% distortion. When we connect the amplifier, we get (it is not an error that F9 and F10 are not shown and F11 is. F9 and F10 were negligibly small, but F11 was a bit higher):

Amplifier				
harmonic	dB	amplitude	squared	
F0	-20.7	0.092257143		
F2	-71.74	0.000258821	6.69885E-08	
F3	-88.25	3.86812E-05	1.49624E-09	
F4	-104.3	6.09537E-06	3.71535E-11	
F5	-107.9	4.02717E-06	1.62181E-11	
F6	-109.3	3.42768E-06	1.1749E-11	
F7	-98.68	1.16413E-05	1.35519E-10	
F8	-150	3.16228E-08	1E-15	
F11	-101.4	8.51138E-06	7.24436E-11	
			6.87578E-08	sumsqur
			0.000262217	sqrtsumsqur
			0.284224117	%
			-50.92678149	dB

FIGURE 8

Some spectrum analyzers have trouble with making the measurement of the harmonics in the presence of the much larger fundamental. To assist with this, a twin-T notch filter can be used to reduce the amplitude of the fundamental (schematic is Figure 9). Unfortunately, this does affect the amplitude of the harmonics as well. Copied below is a frequency response plot (linear horizontal scale) of a filter made using four 0.01uF caps and four 16k ohm resistors (Figure 10).

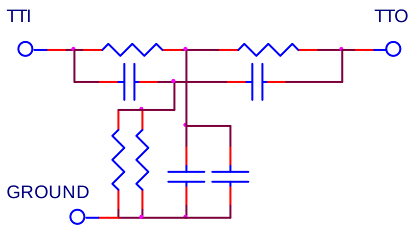

FIGURE 9

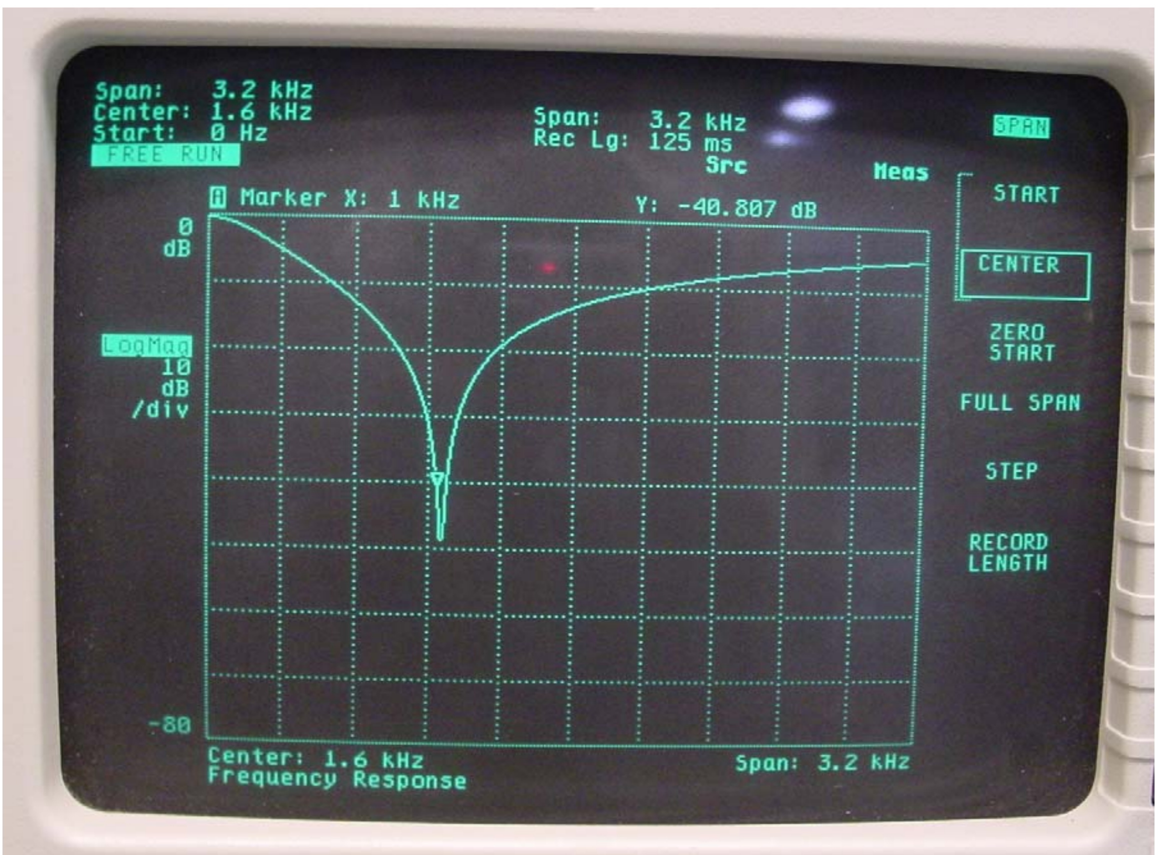

FIGURE 10

Figure 11 below shows the distortion computation done using the Twin-T filter. This shows good correlation with the previous result, so there is confidence that the analyzer can function well in making this measurement in a somewhat large signal-to-noise environment. It also shows that the distortion number is dominated by the first couple of harmonics.

Amp with Filter

harmonic	dB	dB filter	dBtotal	amplitude	squared	
F0	-20.7			0.092257143		
F2	-81.38	9.58	-71.8	0.00025704	6.60693E-08	
F3	-100.9	5.56	-95.34	1.71002E-05	2.92415E-10	
F4	-107.2	3.73	-103.47	6.70656E-06	4.4978E-11	
F5	-150	2.72	-147.28	4.32514E-08	1.87068E-15	
F6	-150	2.09	-147.91	4.02254E-08	1.61808E-15	
F7	-150	1.68	-148.32	3.83707E-08	1.47231E-15	
F8	-150	1.4	-148.6	3.71535E-08	1.38038E-15	
F9	-150	1.2	-148.8	3.63078E-08	1.31826E-15	
					6.64067E-08	sumsqur
					0.000257695	sqrtsumsqur
					0.279322615	%
					-51.07787802	dB

FIGURE 11