



after result of a single pass with an Auto-EQ system made by Audyssey. In this case, a well known brand of headphone in the \$300 dollar class is shown being corrected via a probe microphone using a PRO Audyssey MultEQ-XT system.

No attempt to make it better (flatter) was tried - which could be done - it's just to show you the concept and that it does what is expected. The probe tip adapter could have its response compared to the non-probe microphone and any differences noted and used in correction of the final response. I had the opportunity to compare the headphone results against an expensive B&K dummy head system and using a B&K 4182 probe microphone and the agreement was very close. I believe the more accurate is the one shown here as it used real ears (mine) and thus can be individualized for each user.

So, here we are with a great little amplifier for all headphones and a method to obtain better frequency response from your headphone, as well. The combination provides outstanding results at low cost. With higher bias and adequate heat-sinking, this circuit has been operated up to about 12 Watts and will then drive 8 ohm loads at low distortion.

I hope that this headphone EQ approach will become an integrated package that is available everywhere in the future.

Enjoy !!

References and Further Reading

- [1] Knowles Technical Bulletin TB15 "Probe microphone kit application notes."
- [2] Marsh, R.N. - "How Linear distortion can sound non-linear". The Absolute Sound (TAS) #48, 1987 pg105-107, The Cutting Edge.
- [3] Marsh, R.N. - "Direct Coupled Designs." TAS #55, 1988 pg. 97-99, The Cutting Edge.
- [4] Marsh, R.N., Jung, W. - "Picking Capacitors", Part I and II, AUDIO, Feb & March 1980.
- [5] Marsh, R.N. - "A Passively Equalized Phono Preamplifier." The Audio Amateur (TAA); issue 3/80, June 1980.
- [6] B&K probe microphone Model 4182.
- [7] Marsh, R.N. - letter on Servo Control for Elimination of Amplifier Coupling Capacitors, TAA, Issue 5, 1984.
- [8] Marsh, R. N. - "A Complementary Push-Pull Power Supply" TAA, Issue 1, 1988
- [9] Marsh R.N. - "Power Up: An Overview of Power Supply Considerations" TAA, Issue 3, 1983
- [10] Marsh, R.N. - "POOGE 3" TAA, Issue 4, 1985
- [11] Marsh, R.N. - "Understanding Common-mode Signals" AUDIO, Feb 1988
- [12] Marsh, R.N., Jones, B.A. - "A Real Time Audio Analyzer", Popular Electronics, Sept 1977.
- [13] Marsh, R.N. - "Resonances: Getting Beyond Frequency Response". TAS, Sept/Oct 1990
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Power supply

The power supply is not shown as it can be any good, fast, quiet, stable, regulated circuit that provides 12-15vdc at >200mA per rail. There have been many great circuits published elsewhere – including the Internet. To speed up the fab time, the prototype power supply used an excellent Plug-N-Play regulator circuit of series type premade by Belleson – SPJ series. However, I prefer the shunt regulators or a ‘splitter’ type circuit. These are also being called virtual ground circuits. They inherently keep both + and – voltages the same.

Rail splitting wasn’t new then but using high performance shunt regulators in audio was new. I showed a simple example of a shunt regulator/rail splitter in TAA [8]. The subsequent TI part that came out afterwards does the same thing but the maximum current output is too low for these circuits.

While I am on the subject of power supplies, let me bring up another simple yet very effective way to keep the + and – rail voltages the same; Namely, by placing a large value electrolytic capacitor (hundreds to thousands of microfarads) across the rails so the supply voltage will be made the same on each rail under dynamic load conditions. The voltage may vary in magnitude but the two voltages will be kept equal. This is especially useful and practical for power amplifiers where a high current, regulated voltage cost would approach that of the amplifier itself. It is more important to amplifier performance if you keep the dynamic voltage differential of the supply rails to a minimum than what their absolute values are. It also reduces the burden on the amplifier to reject voltage changes on the power supply lines (PSRR). I have used this for twenty years and commercially with great success.

I have not shown film bypass capacitors but, of course, they are always used for highest performance. As I found and first reported decades ago, the primary culprit is the dielectric film used in capacitors which has the largest effect on sound Polystyrene, Teflon and polypropylene are the best for audio. They have the lowest dielectric absorption characteristics which I found to cause audible degradation using *asymmetrical* waveform tests. Symmetrical sine wave tests tend to average out to zero or very low levels. But asymmetrical waveform tests showed 1-10% peak distortion with polar capacitors (mostly second harmonic); see for instance [2] and [4]. At least a minimum of 0.1uF should be used across supplies and electrolytic caps. Often even greater values are best. And, they should be placed at the amplifier circuit and not at the power supply if they are to do the most good.



Device matching

All BJT transistors should be selected to match their compliment in H_{fe} and V_{be} to get the very lowest THD and dc offset voltage and minimal drift. But, I did a lot of testing of various transistors so you won't have to worry too much – even without tight matching, using these transistor part numbers, the harmonics will generally be more than -90db down from fundamentals with a load of 30 ohms. It is primarily second harmonic. No harmonics above the third were seen. The cost of any transistor used here was in the 10-15 cent range for small quantities via the Internet.

The best way to do complimentary matching is with a characteristic curve tracer (e.g. Tek 576). The second best and the easiest way to do the matching of V_{be} and H_{fe} with the bipolar types is just to buy a small hand held portable tester from PEAK Electronic Design Ltd. – Model: Atlas DCA55. I found it on eBay for 50 dollars or less (new). The headphone amplifier THD result shown here (> -100db) is from using this simple tester for device matching.

The 1K pot is for DC trim on the output.... If you have matched your compliments well, the trim will be a minor adjustment to zero on the output. Or, you can replace it with fixed resistors. And, of course, the four output transistors (Q3,4,6,7) need a heatsink for their TO220 package.

The only issue to really deal with are the input jFET's. These devices are not like the devices 2SJ74/2SK170 pair. Those are large geometry devices – needed for low noise – which means high capacitance; highly *non-linear* capacitance. Usually an additional cascoding transistor is required to deal with this capacitance and the distortion created in interfacing. The jFET's used here have very low capacitance. Also, they do not have as wild parameter variations from piece to piece. But, the spread in I_{dss} is still something to deal with if you want the lowest THD and output dc offset. Fortunately, you won't have to pay a lot to get them and finding a matched compliment doesn't take a truck load of parts. A simple test jig will do the trick for you (**Fig 10**). You want two complimentary jFET's that measure close to .8 mA each or 0.8 volt measured across a 1K source resistor. This will put the devices close to their zero TC operating point. You decide the tolerance you want but 5% or better is good and fairly easy to obtain. Expect to get about 20% matches from a batch which will meet the 0.8 volt requirement. I try for better matching which takes more time and samples because I want the absolute lowest possible distortion and dc offset and drift. I also use a Tektronix curve tracer to get exact matches over a range of currents and voltages.

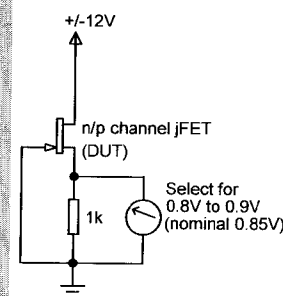


Figure 10: jFET matching jig.