

## Comparing Eight Tubes for Low Power Amplifiers

*The article compares eight different output tubes of low power in Single Ended (SE) mode, both triode and pentode, for compatibility with classical and jazz music listening using Lowther high-efficiency drivers in Teresonic speakers. My gold standard is still the 2A3, but this project showed me that the EL3N is very close. – Damon Coffman*

Even though I never made a career in music (choosing physics instead) my love of music never ceased. At the arrival of our first child, I sold my stereo to pay hospital costs, but quickly hand-build a replacement based on a Popular Electronics article. Thus it was strange that by the early 90's I was not really listening to classical music any more. I'd converted my vinyl to CD's and could afford a decent system by then, but something was missing. On a whim I bought a pair of used Manley Labs mono blocks, picked up a platter and some yard sale vinyl, and found that I enjoyed listening to music again. That sent me back down the valve amplifier road. Over time I've come to recognize Single Ended Triode (SET) amps can closely reproduce a live acoustical performance. SET amps need efficient speakers and that led me to Lowther drivers. Then about eight years ago a few estate sales set me on a new path. At one I purchased 50,000+ vintage tubes and next landed some 3500 records from a serious classical collector. As a kid I'd read the RCA handbook and knew that tube amplification wasn't hard. What I didn't know is how much fun it would be to make amp that sounded so good for so little money.

**Music is for listening.** I care not a whet for specifications – if my ears object, who cares that measured distortion is almost nonexistent? Our ears, instruments, concert halls, and subjective senses are all extremely non-linear. We experience and love music as a combination of all these elements together. SET amplifiers combined with full-range drivers come closest to reproducing the live and intimate concert hall experience. Why full range drivers? Because there is no mechanical phase distortion between complementary harmonics due to separation of low, mid, and high drivers. To my violin-trained ear this phase distortion is obvious and unacceptable. We expect to listen to music as though it were coming from a point source. A PM2A Lowther driver in the Teresonic enclosure sounds like live music in your living room.



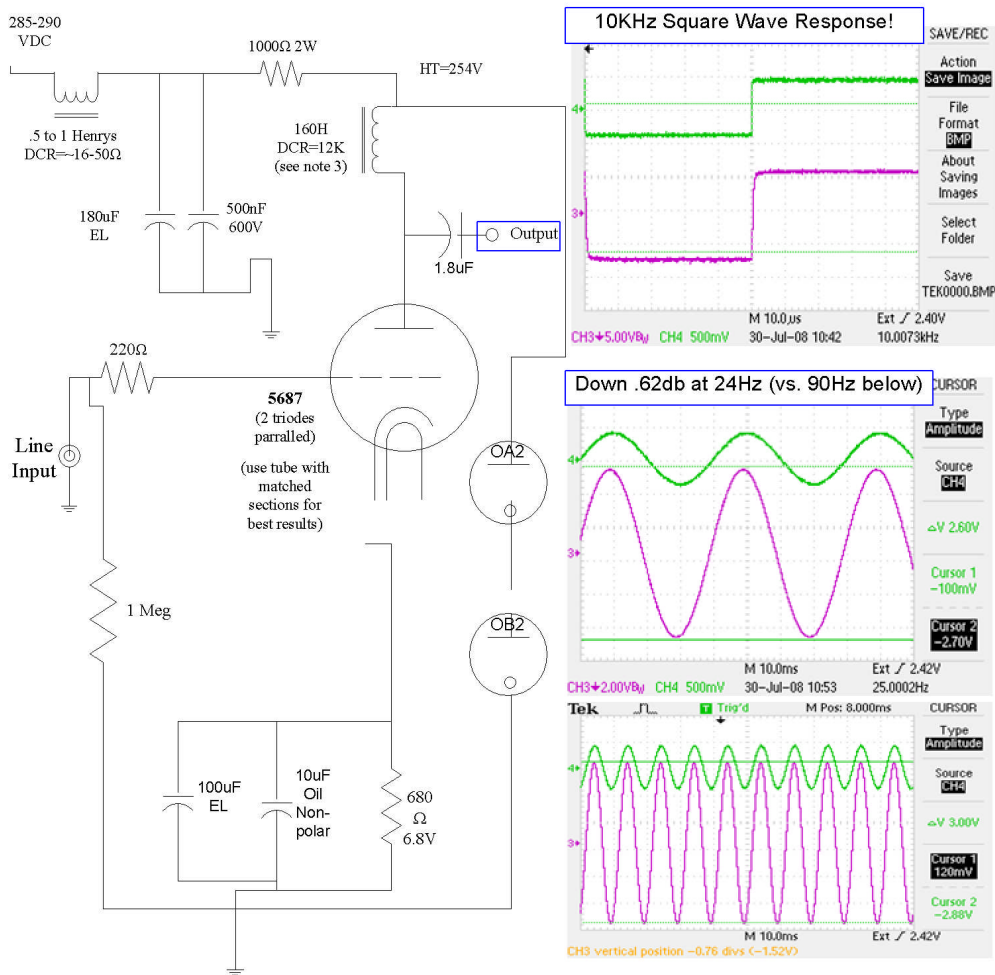
About a year ago my new Teresonic speakers using Lowther drivers arrived. During the early listening phase I discovered my volume setting was always very low. I do tend to listen to music louder (according to my wife), but this is primarily to hear the subtlety in the background—if the clarity of the speaker does not mask the details then the volume can be lower. Lower volume and clarity greatly improves listening as dynamics are expanded subjectively (per the Fletcher-Munson equal loudness curves.) In addition, low volume equals low distortion. This got me to thinking about options of comparing different low power triodes for sound compatibility. If one or two watts are enough, the options for a power amp are huge—such possibilities led to this project. To put this in perspective, consider that many top end speakers have sensitivity of 85 db, compared to 103 db for Teresonic. This means that driving a Teresonic with one and one-half watts equals well over 100 watts driving the other speaker.

The motivation for this project is to make a design that fits almost any DIY'ers budget. Most of current tube amplification world is in the price stratosphere. Surprisingly, one can build an amp for less than \$1000 (or

even \$300 with yard sale help) that equals an \$8,000 commercial amp—if you are willing to make some compromises, primarily in power output. Then you can spend your money where it counts most – at the beginning and end of the audio chain, or on speakers and phono cartridge. I’ve spent hundreds of hours listening to various revisions and freely distribute my results in the hopes that more people will do what I did – pick up a soldering iron and head to the basement (or attic in my case) workshop.

This project includes output tubes that are (mostly) still available, ranging from the esoteric to the nearly free. I chose eight tubes as representative of what the novice DIY’er could do. The design is broken down into the drive and output sections for simplicity.

**DRIVE SECTION:** A choke loaded 5687 provides a gain of 16+ and can swing over 100V P-P without distortion. A drive tube should be able to swing the full bias voltage X 2 without distorting. For example, the EL3N has -8 VDC of bias and thus 500mv P-P input drives to full power. Since a CD player or phono pre-amp will put out 750mv at 0 db (max signal), no extra amplification is necessary. Thus, a passive line stage could work for the EL3N. A normal line stage will allow another 12db or more of amplification. I was able to run all tubes directly from my line stage without any extra amplification in the drive stage.



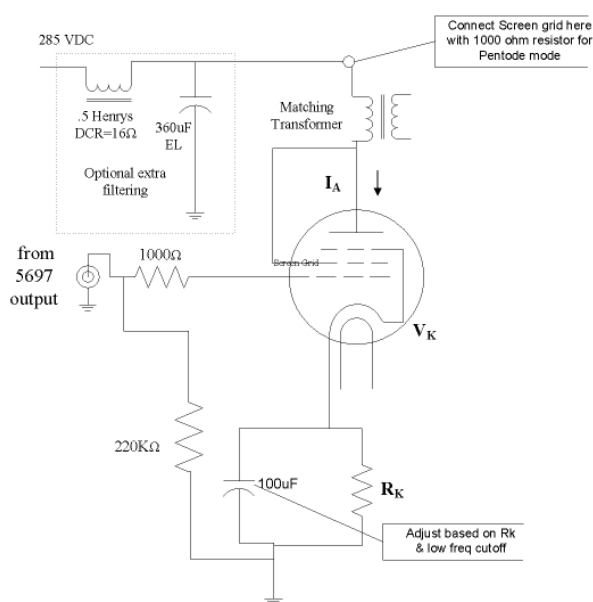
**OUTPUT SECTION:** Single Ended Triodes (SET) power amps are the very essence of simplicity. It is almost impossible go wrong if you follow the manufacturer recommendations. See the table in the output schematic for proper values.

Output Tube	$R_K$	$I_A$	\$\$	Pwr*	$V_{K^{**}}$	~Primary Impedance
6973	300	46 ma	\$100+	1.9/5.5 <sup>1</sup>	-15	4.8K
6V6	300	45 ma	\$30-90	1.5/5.5 <sup>1</sup>	-13	5K
EL3N***	150	20 ma	\$100?	1.0 W <sup>2</sup>	-8.5	7K
807	360	80 ma	\$3-15	1.3 W	-17	4.8K
6DQ6	800	50 ma	\$0.25-1	1.8 W	-41	~2.5K?
E80L	270	24 ma	\$25-45	2.7 W <sup>2</sup>	-6.5	10K
6BQ5	135-150	48 ma	\$20-100	1.5	-7.3	5K
6AQ5	288	45	\$10-30	1.5/5.5 <sup>1</sup>	-12.5	5K
6I6	300	75 ma	\$20-150	2.7/6.5 <sup>1</sup>	-16.5	2.5K
EL-3(Pent)	425	40 ma	same	9 W	-6.0	7K

1 Pentode Mode  
 2 Using 5K transformer  
 \* Pwr – measured 5% 2<sup>nd</sup> harmonic distortion in Triode mode – double in Pentode mode (may vary based on tubes)  
 \*\*  $V_K$  – Grid bias sets the maximum driving input voltage by formula  $V_{in}=2 \times V_k$   
 \*\*\* 3<sup>rd</sup> harmonic is lowest of all in the list at rated power for EL3N tube

Deviate from these values carefully; more power is possible by increasing the current draw, but tube life suffers. All these tubes are pentodes or beam power amplifier tubes. To run a beam power or pentode tube in triode mode, strap the screen grid to the plate (e.g. for 6V6 this would be pins 4 & 3.) The suppressor grid is internally tied to the cathode, except in the case of the E80L where it must be connected externally (pins 9 & 3).

In pentode mode the power output is usually doubled, but the distortion in the odd harmonics increases.



This may not be a problem when using a high efficiency speaker as you will be at very low output levels and distortion is only discernable as the power output approaches maximum. To run in pentode mode (except for 6BQ6), connect the screen grid to B+ supply with 1000 ohm resistor (see schematic). Alternatively, you can use a transformer with screen grid taps (ultra-linear mode). The E80L is designed to run as a pentode, but it makes a beautiful triode. If using the 6BQ6 as a pentode, follow the breakout schematic and adjust the screen grid voltage to give ~75ma of current draw. This should yield between 150-170 Volts at the screen pin, depending on supply voltage.

**RESULTS:** Ratings are obviously subjective to my ear. I think that most CD and solid state aficionados would initially prefer the 6973, and then over time be wooed to the EL3N or E80L. SET lovers are going to want the EL3N.

Initially I noticed very significant differences between different tubes. This was surprising, but I went with the flow and spent about a week listening to the permutations. I became convinced that I was not hearing tube differences; rather I was hearing the effect of my bench regulated power supplies. The large difference of current between tubes could have a very marked effect based on differences in transient response, etc. Once I connected up the new power supply, “The Beast”, many differences disappeared and a whole new set of subtleties became audible. This exercise underscores the importance of the power supply in the equation – many times a mediocre amp sounds that way simply because of an inferior power supply.

Most of the time when you read a review there is a description of how such and such a musician on such and such a track sounded so and so. When I finish reading those articles I have no idea what it really sounded like – so I haven’t learned anything. I do know that when I listen to music I want to be excited by what I hear. If the recording is a dud, no amount of tube grease will fix it, but if it is great music a great SET amp can surprise you over and over again. My favorite recording of all time is a scratchy 1953 record of Sviatoslav Richter playing the Mussorgsky “Pictures at an Exhibition” in Belgrade in the February. You can hear the audience hacking in the background, but the excitement is palpable. At the finish I want to jump up and shout “Bravo!”

A good 2A3 amp with vintage tubes does wonderful things to great music and has been my favorite amp for a long time. My goal in this project was to find a (vintage) triode strapped pentode that could equal the magic of a vintage 2A3. New tubes from China and Russia are getting better, but they still have a loooong way to go. To do some critical comparison I decided to leave the classical world and pulled out my recording of DiMeola, McLaughlin, and De Luca in “Friday Night live in San Francisco.” This is one of those great recordings where the audience excitement sets you on your toes. The guitar work is so incredible that even the slightest differences in amplification quality are noticeable. With the design of the

#### Measurements and Notes

Equipment: Tektronix TPS 2024 scope, Tektronix AGF 3022 function generator, Hagerman Vacu-Trace analyzer for matching drive tube sections.

Power: Measured at the 5% harmonic distortion point, or -26 dBV for 2<sup>nd</sup> harmonic. This would have been the old ‘RMS’ hi-fi rating. Later ratings allowed 10%, which could double the rated output power. This sounds like a lot but the ear finds the 2<sup>nd</sup> harmonic pleasant and enhancing in the high volumes. On the other hand, very small amounts of odd harmonic distortion are objectionable. I like to see the 3rd harmonic below -48 dBV at full power.

Drive section: Choke loaded circuit gives full gain of 5687. Same result could be obtained using 12B4 but with ½ gain.  $\mu = 17$  for a 5687 thus, 0dB input will drive over 30volts P-P, plenty for many power triodes. Most active pre-amps will easily output +12 dB. This could then drive 300B to full output. Signal is ultra clean up to well over 150 volts P-P. If more gain is absolutely needed use ½ of 5687 as a Plate Follower with 6-12 DB of feedback. This will reduce RF response slightly.

5687 should draw about 10 mA per tube. This leaves voltage regulator drawing 15 mA – right in the sweet spot.

Multi-Amp as this project was named, I could switch between tubes on the fly. If I resisted switching and wanted to listen to the whole track—then I knew that tube was a winner.

The tubes fell into three categories: “yawn”, “very nice”, and “great”. In the “yawn” category is the 807 tube. I can’t recommend this tube in triode mode at all. The RCA manual doesn’t recommend it either, and now I know why. It doesn’t even work for background listening.

In the “very nice” category are all the 6V6 style beam power tubes. In fact, with the upgraded Beast power supply it was hard to find a distinct difference between the 6AQ5, 6V6, and 6L6. This is not surprising since they all have very similar construction. The 6AQ5 is a lower power 6V6 in a 7 pin package used originally in car radios, and the 6L6 is an upgraded 6V6 with higher voltage and higher current. You could make a choice based on cost or availability and loose nothing to quality in this group. (All of these tubes are actually beam power tetrodes, not true pentodes, designed as such to get around the 1928 Philips pentode patent.)

I would also put the 6BQ6B / 6CU6 in the “very nice” category, but it takes a lot more drive voltage so an extra gain stage may be required. The 6BQ6 is a TV sweep tube and can be had for almost free. It is a great tube for guitar amps. I actually found that I preferred the 6BQ6 to the 6L6; the detail and articulation seemed slightly better. If you build a 6BQ6 amp, consider adding a switch to toggle between triode and pentode mode. Also, make sure to put a cage

on the amp—you don’t want a high voltage accident from a child sticking their finger on the plate cap.

The “great” category included a bronze, silver, and a gold medal winner. [Note that all of the tubes in this category are true pentodes, not beam power tubes. RCA claimed that beam power technology sounded just as good as true pentodes, but I beg to differ. ]

**The bronze** winner, 6973, is an ultra clean tube—detail and articulation are truly fantastic.

#### Equipment & Parts:

Line Stage: Cary SLP-05

Phono Stage: EAR 324,

Turntable: Immedia Platter, RPM II tonearm, Koetsu Urushi Cartridge

Digitizing and Playback: Echo Audio Layala 24, 32 bit X 96KHz tracks = 4 GB per record.

Output Transformers: Audio Note (152?) circa 1975. I used 4 ohm tap for 5K ratio.

Power Supply a.k.a. ‘The Beast’: Re-made from an organ power supply. High voltage via solid state bridge feeding a double PI filter with a 4uF oil filled input capacitor; good to 350ma with < 1mv ripple. Independent DC filament supplies good to 5 amps per channel. Variable filament voltage to test audio response using ‘starved heaters’. Weighs about 70 lbs.

Listening Room: Lab: 18’ by 14’ with 10’ cathedral ceiling. Very intimate sound with Terasonic Intregrooms with Lowther PM2A silver voice coil, 16 ohms.

Schematics and tips for the various amps will be also posted at [www.galaxySETlabs.com](http://www.galaxySETlabs.com)



Internally the 6973 is almost identical to the 6BQ5 and 6GK5, but it sounds much better. The 6GK5 makes a really cheap good amp, and the 6BQ5 improves on it somewhat, but the 6973 stands alone in this group. The attacks are all crisp and correct. A cymbal sounds like a live cymbal, which is rarely the case in amplifiers (and never the case from a CD recording). My only objection was that the sound could tend to be a little clinical in some passages. You don't want to be beat over the head with subtlety; you want to be surprised by it. It is kind of like the difference between listening to a violin three feet away and fifteen feet away. At three feet a violin can hurt your ears from the abruptness of the down stroke attacks. At fifteen feet it mellows into an acceptable sharpness. Even so, I could listen to this tube all day.



**The silver** medal goes to E80L as it adds beauty and warmth to the articulation found in the 6973, softening to just the right amount for the Teresonic speakers. The 6973 is a good match for the Medallion II's, but the E80L still gets the nod for musicality. We are talking very minute differences here, ones that may not be detectable in a less sensitive speaker.

**The gold** goes to the EL3N. It is closest to the 2A3 sound of any of the triode strapped pentodes tested. The EL3N makes music exciting – I plan to build a vintage EL3N amp as part of my collection this winter. Historically, the EL3 was created as a round cathode version of the AL3 by Philips in 1936. The EL3N was an improved version of the EL3 with lower filament current and better cathode. The 6V6 was created as a competition to the EL3, while the 6L6 was created to compete with the EL5 – the high power successor to the EL3. The final successor to the EL5 (and EL6) was the EL-34, still loved for its beautiful tone, especially by guitarists. Even in pentode mode, the EL3N is a beautiful and exciting tube. I would like to test this tube using ultra-linear design in the future. SET lovers will want an EL3N powered amp if they can find a source for the tubes; try [www.radiomuseum.org](http://www.radiomuseum.org), (I bought mine in Bangalore, India.) The final wonderful thing about the EL3N is that it is a 'green' tube. Only 20ma is required to run in triode mode, the lowest of any pentode. This means you can use your salvaged preamp transformer to build the power supply and not worry about burning it up.

The first part of my MultiAmp project is complete, although I did not specifically test a few tubes that might be favorites like the 6CA7, or the EL34, or even the 6080. However, there is a lot of information out there on those tubes and I wanted to go a little off the beaten path. The next part of the project will look at comparing direct heated triodes: 45, 2A3, 6A3, 6B4G, 6S4S (or 6C4C, the Russian version of 6B4G). **My gold standard is still the 2A3, but this project showed me that the EL3N is very close.**

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*About the author*

*I am a violinist (a hacker now, but a concert master decades ago) and want the music I listen to, primarily classical and jazz, to sound like live performances. I remember clearly the day I began really listening to music. It was winter 1955. My father had left his college music scholarship to support a new family. We wintered in Calgary and then spent the summers camping in northern Canada close to the oil fields where he worked. On this particular winter day my parents bundled me up and went to an appliance store to choose a record player for the family. We listened to console after console and finally settled on a Philco console record player. It must have been a real sacrifice for I remember the long discussion about the wisdom of spending \$100. My father had been a singer and so I listened to opera by the hour—memorizing librettos and singing along with my favorite arias. In the summers we had a Zenith battery radio that picked up BBC in the far North. Saturday afternoon was sacrosanct. We would listen to Milton Cross with his clipped British accent host the BBC Texaco Opera hour from 2 to 5PM. Then came “The Shadow”, “Gunsmoke”, popcorn on the camp fire, and family singing. Later I began playing the violin and eventually went to college on a music scholarship myself, taking the Philco innards with me. My father and I continued to listen to the Texaco Opera hour together whenever we could until the day they took it off the radio.*