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From the Editor's Desk

Honoring a Legacy

This is an unusual edition of *audioXpress*, because it celebrates the life of Edward T. Dell, Jr., founder and former *Audio Amateur*, publisher, who passed away in February at the age of 88.

Over his long publishing career, Dell single-handedly did more to foster the audio construction hobby than anyone else. He launched *The Audio Amateur* in 1970 and started *audioXpress* in 2002. In 2011, he sold his company's assets—which included *audioXpress*—to Elektor International Media.

Those of us now working for *audioXpress* wanted this edition to celebrate Dell's legacy. We are doing this in two ways. Starting on page 39, we're publishing remembrances of Dell written by authors he inspired over the years. The rest of this issue is filled with the sort of DIY audio projects we hope Dell would have loved.

These projects have a special emphasis on glass audio. Here are just a few highlights:

Bruce Heran writes about the construction of the Poddwatt Series II amplifier—a push-pull, pentode-based amplifier some listeners say sounds as good as, or even better, than a single-ended, triode-designed amp. He calls his design the "Oddwatt," because of its unusual, yet simple, configuration (p. 17).

Burkhard Kainka shares design principles that enable you to make a Class-A FET amplifier produce the "warm sound" of a valve amplifier (p. 30).

Interviewee Adam Clarkson discusses how he used Kickstarter, the online funding platform, to help raise money for the initial production of BlueTube Audio's vacuum tube amplifier. The design puts new-world technology inside the old-world veneer of a classic tombstone radio (p. 28).

Pierre Touzelet explains the self-compensated output power transformer (p. 24). The concept's objective is to cancel DC magnetic flux.

And, of course, our regular columnists offer additional interesting content.

Regards,
Mary Wilson
editor@audioxpress.com

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WORLD TUBE DIRECTORY | LIS LOUDSPEAKER INDUSTRY SOURCEBOOK

By Mike Klasco and Steve Tatarunis (United States)

High-Polymer Film (Part 2)

Headphones, Microphones, and Other Audio Applications

Exploring the potential of high-polymer piezoelectric film

Last month we explored polyvinylidene fluoride (PVDF) piezoelectric film loudspeakers. Now, our exploration of this technology focuses on its many other successful applications—from headphones, microphones, guitar pickups, and accelerometers to its ancient use in phono cartridges. Finally, we will examine recent developments in fourth-dimension (4-D) audio—PVDF electro-active polymer (EAP) products for haptic vibration in headphones, which creates an extreme bass sensation. Aside from these applications, we will discuss why PVDF film transducers are relevant for audio design including their lighter weight without neomagnetic structures, the piezoelectric effect without the use of lead (which is now used now in piezo ceramics), and the availability of semiconductors for driving the high voltage needed for high-polymer films.

In Part 1 of this article series, we touched on PVDF's slow acceptance into mainstream audio, but let's take a closer look. What we have is transducer technology with unique capabilities and design advantages. Lightweight and flexible, piezoelectric film transducers can serve as highly reliable low-cost alternatives to more expensive speakers, headphones, mics, and musical instrument sound pickups.

HEADPHONES

The flat frequency response over a wide range is a consequence of the PVDF polymer film's softness, which eliminates the self-ringing found in brittle materials such as piezoelectric ceramics. In the late 1970s, Pioneer introduced a well-reviewed series of PVDF film headphones—the SE-300, the SE-500, and the SE-700 (see **Photo 1**). These products were advertised as being "the world's first high molecular polymer stereo headphones."

Photo 1: The Pioneer SE700 Headphone was among the first PVDF film headphones on the market.

PVDF film headphones have three practical downsides. First, they are barely efficient enough to play from the average receiver headphone jack let alone a smartphone's headphone output. Second, a piezoelectric device is electrically a capacitor, and some amplifiers have difficulty with reactive lossy loads. This aspect is a real deal breaker for mainstream acceptance today. High voltages are required and PVDF film transducers aren't very efficient. However, the classic step-up transformers aren't pocket portable. On the other hand, a purpose-built high-voltage swing amplifier that can drive lossy capacitive loads is readily achievable, but it requires integration into the headphone. Since PVDF requires high voltage and not high power, the power amplifier necessary to drive PVDF film loudspeakers could be designed with much lower power/current requirements yielding a more efficient, compact, and economic system. Today, DC-DC and boost converters, voltage doublers, and the like are inexpensive, readily available high-efficiency power integrated circuit (IC) devices. Third, PVDF stretches and it's difficult to obtain enough excursion from the semi-tensioned PVDF film diaphragm for it to reproduce bass at high output.

In the 1980s, Sony also had a development project for PVDF film. Toshitaka Takei, the team's lead developer, designed a loudspeaker using piezoelectric film. Because of the difficulties driving them with existing amplifiers, development at Sony was halted. While Sony never commercialized the product, Takei eventually left Sony and founded TakeT around 2003, a low-production and expensive headphone manufacturer that uses PVDF film (see **Photo 2**).

Totally unique, TakeT's approach was to form the PVDF film into a variation of Dr. Oskar Heil's air-motion-transformer invention. This is a brilliant idea as it provides both stiffness through topology and more excursion and compliance though the corrugations (much like a spider/damper gets its excursion from the corrugations rather than stretching the fabric itself). Besides its headphone line, TakeT also manufactures a PVDF film super tweeter.

DIGITAL LOUDSPEAKER AND HEADPHONES

Digital loudspeakers and headphones that can provide direct conversion of sound from digital sources have been theorized for decades. PVDF has the bandwidth and may lend itself to this, but let's save this for a future article in our series.

Another "science project application" for PVDF film is focused ultrasonic beam parametric array speakers that can place

Photo 2: The TakeT H2 headphones' design resolves the low-frequency problems of limited excursion by using a piezoelectric air motion transformer.


Photo 3: Holosonics's Audio Spotligh AS-24 creates sound in a narrow beam. (Photo courtesy of Holosonics.)

audio in a specific location over long distances. This category has a few players, but Woody Norris's ATCO (now LRAD, which stands for long-range acoustic device) probably made the most hype. Currently, this technology was spun off to Parametric Sound. This unique field includes HyperSonic Sound (HSS) from TK Geomedia and Audio Spotlight from Holosonics (see **Photo 3**). A few others have dabbled in this esoteric field including Sennheisser's AudioBeam and Mitsubishi Engineering. Others have patented variants but not commercialized their inventions. Implementations have included arrays of piezoelectric mics (used as ultrasonic radiators), electrostatics, and PVDF film.

PVDF MICROPHONES

Back in the 1970s, the Allen Clark Research Centre in England reported on the design of a pressure-operated PVDF microphone. Later, the Plessey Company reported on a noise-canceling first-order pressure-gradient-operated microphone using PVDF elements in a bimorph edge-clamped configuration. As with electrets, the mass was small and exhibited high immunity to vibration pickup. The advantage of the PVDF design was its immunity to stray magnetic fields, eliminating more costly assemblies.

Extensive research in PVDF transducer technology was also conducted by the Matsushita organization in Japan. At the Audio Engineering Society (AES) Convention in 1977, Naono, Rikow, et al, presented the most comprehensive report to date concerning PVDF microphone applications. They detailed curvature mode of operation PVDF elements with design equations and experimental models.

PVDF mics were theoretically and experimentally analyzed with cylindrical and spherical diaphragms at the Technical University of Darmstadt in Germany. Researchers demonstrated that geometries were possible with PVDF that offered good mechanical and thermal stability. The PVDF also made it possible to vary the diaphragm tension and damping with a back plate/support mechanism.

In the communications sector, Telephonics became interested in the possibilities afforded by PVDF and marketed a variety of low-profile, noise-canceling, boom microphones for telecommunications headsets. Generally, the microphone element in these types of systems is located in the earpiece assembly (making noise-canceling impossible); however, the PVDF element can be made small enough to fit at the end of the boom and provide noise-canceling characteristics.

Countryman Associates introduced a lavalier microphone, the Isomax TVH. Countryman claimed the microphone was the first to use "active vibration isolation," which the company claims to yield 30 to 40 dB less handling noise than other lavalier microphones. The "active" element is a PVDF diaphragm used for noise-canceling. The use of PVDF as a sensor (e.g., the Countryman mic) is just one of many vibration and sound sensor applications utilizing PVDF film.

SOUND AND VIBRATION PICKUP WITH PDVF

Piezoelectric film technology's unique physical properties, size, and performance characteristics make it especially useful for implementation into existing applications as an alternative to a standard-sized piezoelectric accelerometer, where space constraints, cost, or design flexibility may be of concern. It can also produce voltage in proportion to compressive or tensile mechanical stress or strain, making it an ideal dynamic strain gauge.

For example, in subwoofer applications a small piece of PVDF film attached to a loudspeaker cone or voice coil collar can serve as a transducer in a feedback/correction circuit. In another application, musical instrument contact transducers can be easily made from PVDF film. Raad, a Canadian musical instrument manufacturer, produced a line of instruments including violins, violas, cellos, and double basses with integral PVDF elements as contact pick-ups. Gibson, the legendary guitar manufacturer, produced a line of acoustic guitars with a PVDF film permanently mounted in the guitar, which functioned nicely as a contact pick-up. Because this type of pick-up design uses PVDF film's bending mode, it is less susceptible to feedback than piezoceramic accelerometer type pick-ups.

Piezoelectric film technology has been successfully used as a low-cost shock and vibration sensor within computer hard disk and CD-ROM drives, where space is at a premium and mass loading is a concern. Within these applications, mechanical shocks (e.g., those caused by a laptop dropped on the floor) can send a computer disk drive's read/write function off track, possibly overwriting good, adjacent track data, causing memory loss, or destruction of files. Piezoelectric film shock sensors offer a compact, lightweight solution within such sensitive electronic device applications.

SECURITY APPLICATIONS OF PVDF FILM PICKUPS

Imagine a cable is strung or woven along a chain-link fence. The cable can be used to detect unusual acoustic noise signatures occurring on the fence and acts as a microphone from which security personnel can effectively "listen" for perimeter activity. For example, any attempt to cut or climb the fence is immediately detected. Another approach is to bury a piezoelectric cable a few centimeters underground along a security perimeter. When buried, the cable becomes an excellent microphone for detecting footsteps or vehicle activity.

PVDF's moisture resistance also lends itself to towed-phased arrays for sensing and signal feedback for certain naval applications.

PVDF FILM'S LIMITED COMMERCIALIZATION

While PVDF film has many appealing characteristics, it has not developed the broad commercial appeal that its advocates anticipated. While much audio engineering work was undertaken in the 1970s, the existence of this groundbreaking work is virtually unknown to the Chinese audio companies building speakers, mics, and headphones today.

The amplifier drive issues that blocked PVDF film acceptance as a "drop-in" alternative to electrodynamic transducers are less relevant as there are many integrated solutions from soundbars to docking stations where application-specific amplification is used. PVDF film's high amplifier rail voltage and drive voltage (yet low power) is easy to handle with today's technology and voltage doublers, boost converters, DC-DC converters, and so forth are ICs that can be readily and inexpensively designed fit.

Will PVDF film find broad acceptance or will it remain a niche technology? One opportunity is Vivitouch with its haptic sensory enhancement. Perhaps other initiatives will follow. *aX*

 By Richard Honeycutt (United States)

Selecting a Power Tube

Each vacuum power amplifier tube has its benefits

The first audio power tubes manufactured were power triodes. Some power tetrodes have been used over the years, but early tetrodes were subject to self-oscillation due to a negative-resistance "kink" in their plate characteristic curves. In 1935, J. Owen Harries discovered that proper spacing of the plate with respect to the screen-grid-to-cathode distance would maximize the power tetrode's efficiency and reduce secondary emission. Since the "tetrode kink" was produced by secondary emission, the "Harries Valve" eliminated the kink. By this time, the power pentode had been invented and patented by Philips, a Holland-based company. With a higher voltage gain than power triodes, the pentodes were quickly adopted.

BEAM POWER TUBES

In 1936, RCA developed the 6L6 beam power tube shown in **Photo 1**, in which Harries's innovation was accompanied by replacing the suppressor grid with "beam-forming plates." This design worked well, and since the 6L6 is a "beam power tetrode," it evaded the Philips patent on power pentodes. The 6L6 is an octal-base tube, and the original version had a metal envelope. The 6L6G, the 6L6GA, the 6L6GB, the 5881, the 5932, the 7027, and the 6L6GC shown in **Photo 2** were later developed. Their glass envelopes enhanced radiation cooling of the plate and permitted higher maximum plate dissipation ratings. The original 6L6 had a maximum plate dissipation of 19 W, whereas the 6L6GC is rated at 30 W. There is also a tube numbered 6L6WGB, which is electrically identical to the 6L6GC, but is ruggedized for military or airborne use. (The "A," "B," and "C" are revisions, so strictly speaking, the "WGB" is a ruggedized 6L6GB, which may not handle as much plate voltage as a 6L6GC. The tube manual specifications are not consistent.)

Photo 1: The original 6L6 had a metal envelope.

Other popular beam power tubes include the 6V6, the 6550, the 6BQ5/EL84, the KT66, the KT88, and the KT90. The 6V6 is a lower-voltage, lower-power (350-V, 14-W) beam power tube (see **Photo 3**). It was designed in 1937 and used mostly in single-ended output stages of radio and TV sets. The 6V6s have also been used in push-pull configurations for Hammond organ power amplifiers and guitar amplifiers. Two 6V6s in push-pull can output about 14 W.

The KT66 tetrode is the European version of the 6L6GC. The 6550 shown in **Photo 4** is a higher-voltage, higher-power tube similar to a 6L6GC. It is rated at 600 V with a 35-W plate dissipation. The 6L6GC is rated at 500 V with a 30-W plate dissipation. Its European counterpart is the KT88, which is almost identical, but is rated at 40-W plate dissipation. The KT90 is another similar tube, with a 50-W rating.

The 5881 was advertised some years

Photo 2: The 6L6GC has a glass envelope.

Photo 3: The 6V6 is basically a lower-power 6L6.

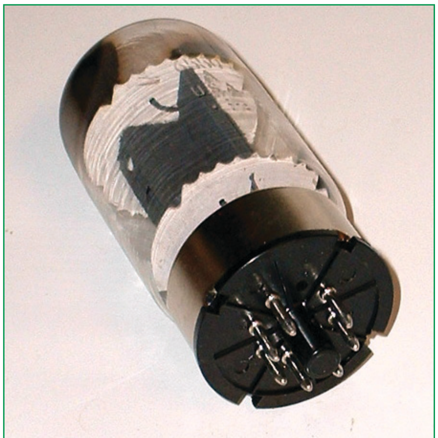

Photo 4: The 6550/KT88 are big brothers to the 6L6GC.

Photo 5: The 5881 is rated between the 6L6GC and the 6V6.

ago as a "ruggedized 6L6GC" (see **Photo 5**). But with ratings of 400-V maximum plate voltage and 23-W maximum plate dissipation, it should not be used to replace a 6L6GC. The 7027 shown in **Photo 6** performs similarly to the 6550. It has the same maximum plate voltage and power ratings. It was used in some Ampeg guitar amplifiers and in some Altec-Lansing commercial audio amplifiers.

The 6L6GC, the 6V6, the 6550, and the 5881 all have octal bases and use the "7AC" basing configuration shown in **Figure 1**. The 7027 is also an octal-base tube, but it uses the "8HY" base. **Figure 2** shows that the screen grid is brought out to pins 1 and 4. The control grid is brought out to pins 5 and 6 can make the 7027 unworkable as a plug-in replacement for the 6L6GC or its "7AC" cousins. It all depends on whether the original amplifier builder used pins 1 and 6—which are not connected to anything in the 7AC-base tubes—for convenient tie points in the circuit. If they are used as tie points, it is unlikely that these points should be connected to the screen and control grids, respectively. Plugging in a 7027 might let the smoke out of the components.

The remaining popular beam power tube, shown in **Photo 7**, is the 6BQ5/EL84, which has a miniature nine-pin base. With a 300-V maximum plate voltage and 12-W maximum plate dissipation, it is a bit less powerful than a 6V6, but it has been used in similar circuits.

The 6146B is a beam power tube that is occasionally used in audio. Introduced by RCA in the early 1950s as an RF power amplifier, this tube is rated for a 600-V maximum continuous plate voltage and a 27-W plate dissipation. A push-pull pair of 6146Bs can produce 100-W output in Class AB_2. An unusual feature of the 6146 is that its plate connection is brought out to a cap atop the glass envelope, which enables better RF performance, but it makes no difference at audio frequencies.

Another immigrant from the RF beam power tube camp is the 807. Rated similarly to the 6146B (600-V maximum on plate, 25 W plate dissipation), the 807 also uses a plate cap connection, but it has a five-pin base rather than the 6146's octal base. In the past, the 807 was often used in commercial audio amplifiers.

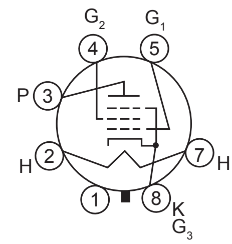

Figure 1: The 6L6, the 6V6, the 5881, the 6550, the KT88, and the KT99 use the 7AC base.

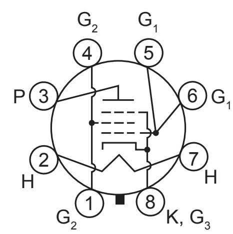

Figure 2: The 7027 uses an 8HY base.

Photo 6: The 7027 is similar to the 6L6GC, but it's not a plug-in replacement.

TRUE POWER PENTODES

By far most of the audio power amplifier tubes used today (in fact, since 1940) are power pentodes or beam power tubes. The EL34, the 6CL6, the 6F6, the 6G6, and the 6K6GT are some examples of true power pentodes. Some musicians prefer power pentodes as output tubes in electric guitar amplifiers because of their higher distortion characteristics, which are partially the result of higher transconductance, which leads to higher gain in the amplifier circuit. For example, a 6L6GC operating with 250 V on the plate has 4,700-microsiemens (µS) transconductance, compared to 11,000 µS for an EL34 power pentode under similar conditions. Since voltage gain is directly proportional to transconductance, the EL34 would have about 2.34 times the gain of a 6L6GC in the same circuit.

Photo 7: The 6BQ5/EL84 is a miniature tube that performs similarly to the 6V6.

The EL34 (the KT77) power pentode was introduced by Mullard in 1953—unlike the 6L6, the EL34 has its suppressor grid connection brought out to a separate pin (pin 1) as shown **Figure 3**. Its heater draws 1.5 A compared to 0.9 A in the 6L6. However, Sylvania (and possibly GE) marketed a tube similar to the EL34 as a 6CA7, which not only was packaged in a markedly different "fat boy" envelope, but used a beam-forming plate much like a 6L6. Although the 6CA7 and the EL34 tubes have similar (but not identical) characteristics, they are made very differently. Both are widely used in high-end guitar amplifiers because they are characterized by greater distortion at lower power than

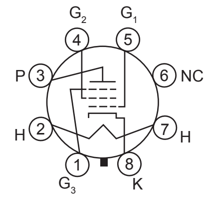

Figure 3: The EL34 uses an 8ET base.

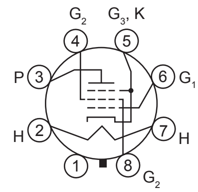

Figure 4: The 7591 uses an 8KQ base.

the 6L6, the 6550, and the KT66. The EL34 is found in many British guitar amps (e.g., Marshall and Hiwatt) and is associated with the "British Tone." The 6L6 is generally associated with the "American Tone," exemplified by Fender and Mesa Boogie amps.

The 7591 and the 7868 are almost identical power pentodes in that they have 550-V maximum plate voltages and 19-W plate dissipation limits. Thus, they can produce about 40 W when used in a push-pull pair. The difference between these tubes is the base style. The 7591 uses an 8KQ octal base (see **Figure 4**). In contrast, the 7868 has a 9RW Novar base. An Internet search will reveal that these tubes have become the target of inquiry by musicians/hobbyists in search of a "new, different" sound.

SINGLE-ENDED POWER TRIODES

Many fanciers of hollow-state audio equipment prefer single-ended (not


Photo 8: The Western Electric 300B is one of the most popular power triodes.

Photo 9: The 2A3 is another popular, more recent power triode.

push-pull) power triode-based amplifiers rather than power pentode- or beam power tube-based ones. Their preference is due to the power triodes' particular distortion signature, as discussed in previous articles. True purists prefer to use the Western Electric 300A or 300B power triodes shown in **Photo 8**, in spite of their astronomical price (ranging from upward of \$100 each for modern copies to almost \$1,000 each for genuine Western Electric tubes). The 300B is rated at 400-V maximum plate voltage and 36-W maximum power dissipation. With 350 V on the plate, and a 74-V control-grid bias, the 300B has an amplification factor (µ or mu) of 3.9. One 300B used in a Class-A amplifier can produce approximately 7-W output.

A somewhat more recent, lower-cost alternative to the 300B is the 2A3 power triode (see **Photo 9**). It is a lower-power tube rated at 300-V maximum on the plate and 15-W maximum power dissipation. With 250 V on the plate, and a −45-V control-grid bias 2A3 has an mu of 4.2. In a Class A circuit, it can output about 3.5 W.

Another alternative for power triode performance is to use a power pentode or beam power tube with the screen grid strapped to the plate and the suppressor grid or beam-forming plates strapped to the cathode (this latter strapping is done internally in some tubes, such as the 6L6 family). A triode-connected 6L6GC will handle a maximum plate voltage of 500 V, and has a power dissipation of 30 W. With 450 V on the plate and a −20-V control-grid bias, the mu is 8.

In a traditional single-ended Class A triode power amplifier, both the DC and the AC component of the plate current flow through the output transformer's primary winding. This can cause core saturation of the transformer, with a lot of resulting distortion. Inserting a gap in the transformer core prevents core saturation; however, the gap decreases primary inductance and limits bass response. To avoid the reduction in bass response, a larger output transformer (more windings than would be needed without a gapped core) can be used to increase the inductance.

An alternative circuit called the "parafeed amplifier" feeds the plate from the B+ supply through a high-inductance choke. A coupling capacitor then blocks the DC component from passing through the output transformer, preventing saturation.

Next month, we'll examine a few hollow-state rectifiers. *aX*

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Poddwatt Series II Stereo Integrated Valve Amplifier

Latest DIY version improves on simply configured Series I

By Bruce Heran (United States)

This article focuses on the Poddwatt Series II stereo integrated valve amplifier, a project with roots that go back more than four years. The design continues to be relevant and to evolve.

The original Series I amplifier was nearly a nonstarter, as I didn't see the use of a small, low-power stereo vacuum-tube amplifier. I was caught up in the horsepower race and thought bigger was better. Nothing less than a pair of KT77 tubes would do. KT88s would be even better. Regardless, I designed a small amplifier based on three different concepts combined in a way that, to the best of my knowledge, had never been previously done (see **Photo 1**). Even now, many people have written me to say such a small vacuum tube amplifier can't possibly work, or if it does, it won't be any good. Well, naysayers, not only does it work, it works extremely well.

I call the basic design an "Oddwatt" because of its "odd" configuration. It is now used in an entire family of amplifiers up to 45-W RMS per channel. I do need to put in a disclaimer. I am both co-owner and principle designer for Oddwatt Audio, which provides vacuum tube amplifier kits, and its pending VC Audio Labs division. An earlier version of the amplifier has been available as a commercial kit, as are others in the lineup.


Photo 1: This original Poddwatt amplifier was built in 2008.

The amplifier in this article is an evolutionary step up from the ones currently available. While the original amplifier is excellent, it was designed as a "budget" project for DIYers. It turned out well and has found favor with individuals who use high-efficiency speaker systems. These individuals generally choose single-ended triode (SET) designed amplifiers. Often, they won't even consider using a push-pull pentode-based amplifier—that is, until they hear this one. I have been told on several occasions the Poddwatt sounds like a SET, but better. I leave that up to others to determine. My sense is that its sound quality is related to the design simplicity and the few components that are actually in the signal chain.

Enough background. It is time to get into the Poddwatt Series II's details (see **Photo 2**).

THEORY

Because this amplifier operates differently from the vast majority of amplifiers, it's necessary to go into a fairly in-depth description of how it works.

The amplifier has two stages. The first stage is a series (or shunt) regulated push-pull design (SRPP). This configuration is greatly misunderstood in the audio community. (I will not go into detail why.) But if a SRPP is used as a voltage amplifier (there are no current demands on it), it is possible to achieve excellent gain, linearity, low distortion, and good power-supply noise rejection.

The second stage combines an old design from about 1948 (a later version was published in 1961) with a somewhat newer twist.[1] The claim that the early versions were hi-fi may have been appropriate at the time, but they fall far short of that now. I suspect the original circuit creators would be amazed by the


Photo 2: The Poddwatt Series II stereo integrated valve amplifier is a step up from previous versions.

current performance level. The original designs used pentodes and fixed cathode resistors. Mine uses pentodes in ultralinear mode with a cathode-constant current source. The output stage is self-inverting. There is no phase inverter driving it. The SRPP provides a signal to only one output tube.

At first glance, the second output tube seems to have no function, as the grid is tied to the signal ground (via a capacitor and resistors). A small lesson from "Tubes 101" is in order here. The current flow through a tube is controlled by the potential voltage difference between the cathode and grid. If you look at the circuit, the tubes share a common cathode load. I'll explain how that functions shortly. In a true Class-A amplifier such as this one, the cathode current is constant. So if the "driven" tube gets a signal to increase the current flow, it will simultaneously result in an increase in the voltage at the cathode. This will increase the voltage between the grid and second tube's cathode (a negative value) and reduce that tube's current flow. Remember, that grid was at ground potential, so a positive increase in the cathode voltage will force it to conduct less. This creates a seesaw-type effect. This action was well known in the past, but it was difficult to use in a hi-fi application.

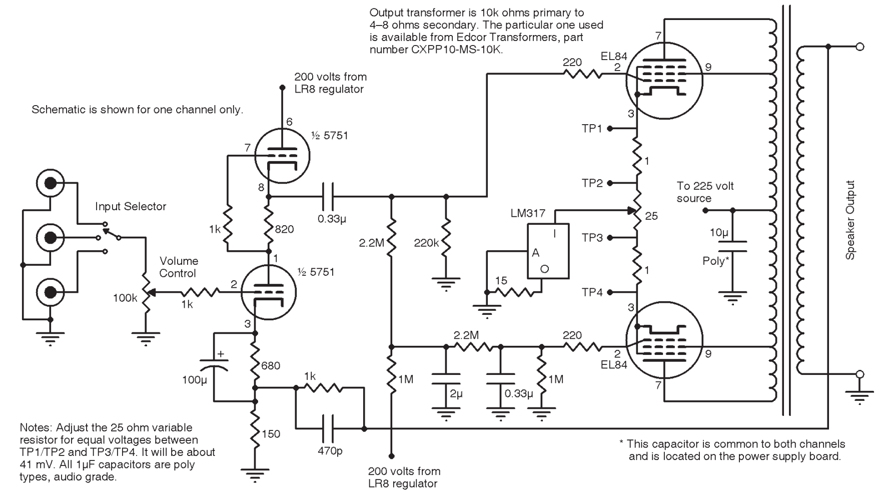

Figure 1: This is the main schematic for the Poddwatt Series II stereo valve amplifier. The amplifier has two stages. The first stage is a series-regulated push-pull design. The second stage uses a solid-state voltage regulator in each cathode circuit.

This brings me to the second part of the circuit. In the 1970s, National Semiconductor introduced a family of solid-state voltage regulators. These are three-terminal devices that resemble power transistors. They can also be used as accurate and robust constant-current sources. So, my design uses one in each cathode circuit to establish the operating point for the stage. Purists would cry foul because I put a solid-state device in a tube amplifier. My response is that I want to reproduce music and I really don't mind mixing components.

The current level I chose is 82 mA per pair of tubes. This is comfortably within the tubes' dissipation rating at the supply voltage (B+) chosen.

The 25-Ω variable resistor in between the cathodes is a balancing device. It enables the shifting of a small amount of DC voltage from one cathode to the other. With fairly matched tubes, this is sufficient to achieve equal current flow though the tubes when idle. The question I am always asked is about "bias" for the tubes. In this design, the question is not relevant. The constant current source (CCS) will automatically adjust the cathode voltage to achieve a correct bias. Combining the SRPP driver/voltage amplifier with a Class-A, push-pull self-inverting output stage (using a constant current source) results in a deceptively simple amplifier that performs well.

Since the first amplifier was built in 2008, I have incorporated a number of refinements. The most obvious is the use of a small positive voltage on both output tube grids. This would seem to be the wrong thing to do and, indeed, in a different design it would be. This small voltage increases the voltage on the cathodes by a similar amount. But because of the CCS, the current remains the same. The voltage's purpose is to account for the nonlinearity of the LM317 integrated circuit, a popular adjustable voltage regulator, at potentials below 4 V. The effect is that the amplifiers are linear up to maximum output.

An additional change from the earliest amplifiers is the use of a capacitor and resistor in the "slave" output tube's grid circuit. This also improves linearity, as both tubes then have approximately the same grid impedance.

I use a very small amount of negative feedback to ensure amplifier stability. The amount has virtually no effect on the audio range but precludes the exciting of the self-resonant point of the output transformers (roughly 60 kHz).

It also means that the output transformer's phase is critical and needs to be reversed from normal use. Thus, as astute readers would conclude, the amplifier inverts the signal. The schematics shown in **Figure 1** and **Figure 2** provide more detail.

CONSTRUCTION

I admit it. I'm lazy. The project was built on a chassis from one of the early kits (see **Photo 3** and **Photo 4**). After all, it is pre-punched and stenciled. A standard-size chassis available from Hammond is all that is necessary. (But if you could see how great I am with a drill press, you would understand why I used the kit chassis.) The top cover is also from the kit, but ones virtually identical to it are also available from Hammond. The amplifier's layout and construction are not critical; however, good wiring practices are recommended. The amplifier's interior is shown in **Photo 5**.

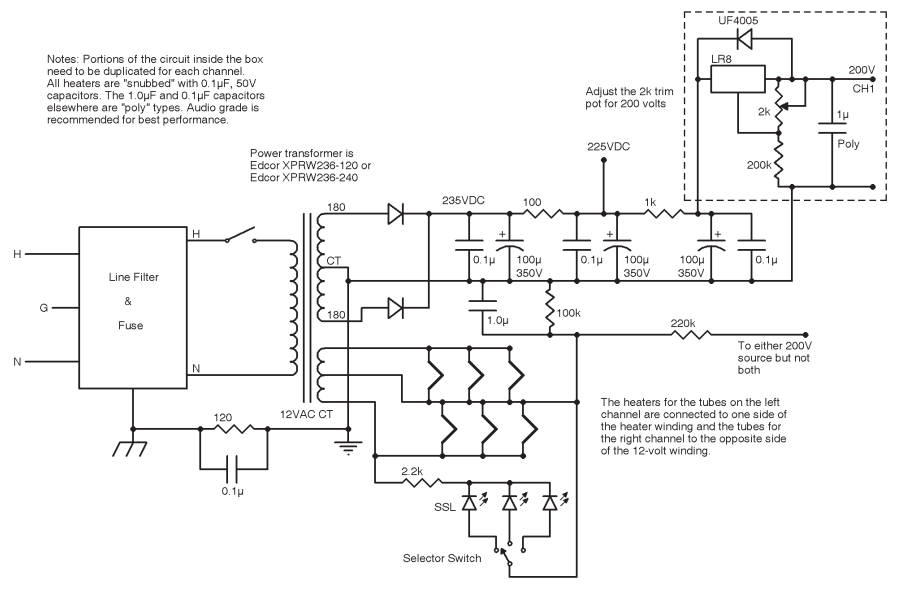

Figure 2: This schematic shows the Poddwatt Series II power supply.

The power supply can be different from the one provided in the schematic as long as the B+ is between about 225 and 250 V and it provides either 6 or 12 AC (with center tap) to the heaters. The Supertex LR8 integrated circuit regulators take care of the lower B+ on the SRPP and are valuable in achieving the high signal-to-noise ratio (SNR) in the power supply.

Additional important considerations include keeping the signal and power conductors separated (and when they cross, doing so at right angles); having the power and output transformers at right angles to each other; using shielded cable from the inputs to the selector switch and volume control; and being aware of ground loops, particularly through the input wires' cable shields. If you use the ground bus, which I'll mention later, only ground one end of the shields. Use quality components, keep heat-producing components away from capacitors, and have generally neat wiring. Make certain that no portion of the heater circuit is connected to the ground. To prevent tube failure (by exceeding the heater to cathode voltage rating of the SRPP), it is necessary to apply a modest DC reference voltage to the heater circuit. This also reduces the overall noise level in the amplifier by a few decibels.


Photo 3: The author built his Poddwatt Series II project on a chassis from one of the earlier kits. Here is a front view of the kit-built Poddwatt Series II.

The heatsinks on the LM317s should be either on top of the chassis or in a location that has vent holes above and below. Use insulating kits on them so they don't short out with each other (if you use a single, larger heatsink) or short out to the chassis. One watt each of dissipation may not sound like much, but when it is in a confined space (e.g., the chassis), it can easily raise the temperature to a point where some components (e.g., the capacitors) will fail.

Pay attention to the grounding of components and circuitry. I like to use a modified bus arrangement—one bus for all the audio components that originates at the input jacks and a second one that runs through the power supply. I tie both together at the input-jack ground connection. I also run a Type X2 capacitor with a parallel resistor to the chassis from that junction. It is important to prevent ground loops in audio equipment, and this arrangement works well. It also enables the chassis to be a ground potential shield that reduces electromagnetic interference (EMI) pickup. It is a safety device should something internally fail and short out to the


Photo 4: This shows the rear view of the Poddwatt Series II.

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chassis. This works best with a three-wire AC main. You may have to adapt the circuit if your system does not have that arrangement or it is prohibited by your electrical codes. In such cases, follow the normal arrangement.


Photo 5: The interior of the assembled amplifier is shown.

OPERATION

Before applying power to any equipment for the first time, recheck the circuit. Look for loose components, terminals that somehow didn't get soldered, short circuits (things touching that shouldn't), and so forth. There are many ways to first power up something, but the method I prefer is to put in the tubes, fuses, and so forth, turn the power switch to "on," then (without touching the chassis) plug it in. If it properly heats up, then proceed to set it up. If it blows the fuse, then some additional checking is needed to locate the problem. If it properly powers up, you can proceed to balance the tubes.

At this point, it is not usually necessary to attach speakers or load resistors to the outputs. But it is necessary to ensure the volume control is set at a minimum.

Using a digital meter (analog is fine, but not generally as precise), measure the voltage across the 1-Ω cathode resistors. The sum of voltages for each pair should be in the 80-to-85-mV range split in half for each tube. Adjusting the 25-Ω variable resistor should enable you get the two halves equal to within 1 mV. If the combined reading or either half is more than 85 mV, there is a fault. There are two common problems that can cause this. First, it could be a problem in the grid circuit of one of the EL84 tubes that makes it impossible to balance the pair. Second, it could be incorrect wiring of the LM317. If it is incorrectly connected, it can fail and cause excessive current flow. Sometimes, you can correct the error and it will be okay. Often though, you will need to also replace the LM317. Fortunately, they are inexpensive.

Occasionally, an amplifier's layout will cause it to be unstable without a load. If you can't balance the amplifier, then attach either speakers or resistors to the outputs and see if it will then balance. If it comes close but you can't get equal current flow, turn it off and swap the tubes in that pair. Sometimes, even in matched pairs of tubes, one will not like to have the grid on the ground like the slave tube. If they still won't balance, then the tubes are not matched enough to use as a pair. Try other combinations with all four tubes. I recommend JJ Tesla and Electro-Harmonix tubes, as they have always balanced well. Others may work.

For the driver tube, the best I have found is the NOS JAN Philips 5751; a close second is the new production Sovtek 5751. You can use any of the 12AX7 types, but I did not find any that sounded as good as the 5751s. The new JJ 5751 (from JJ Electronics, formerly Tesla) does not work well in this amplifier. The prototypes measure 10 Hz to 30 kHz ±0.5 db at any power up to 4-W RMS. Distortion is between 0.2% and 0.5% at any frequency between 20 Hz and 20 kHz at 1 W. It reaches 1% at 4-W RMS. Signal-to-noise is 87 db below 1 W. I rate the maximum output at 4 W per channel, but a few more are available with increasing distortion.

LISTENING

At this point, you are ready to use the amplifier. I recommend using full-range speaker systems with a 90-db/W sensitivity for best results in average-sized rooms.

If built using the components shown in the schematic (particularly the output transformers), you have an amplifier that can accurately reproduce music with exceptionally low distortion and low noise. I have used it on numerous speaker systems, including my potentially difficult-to-drive MartinLogan Vista Electrostatic. They provide almost a purely capacitive load at high frequencies. There are no problems; they just sound great.

If your amplifier doesn't work this way, then something is not right. The most common error is the output transformer's phase (mentioned earlier). The amplifier will work but sound shrill. To fix that, you will need to swap the anode and screen grid leads from one output tube to the other. Good listening. *aX*

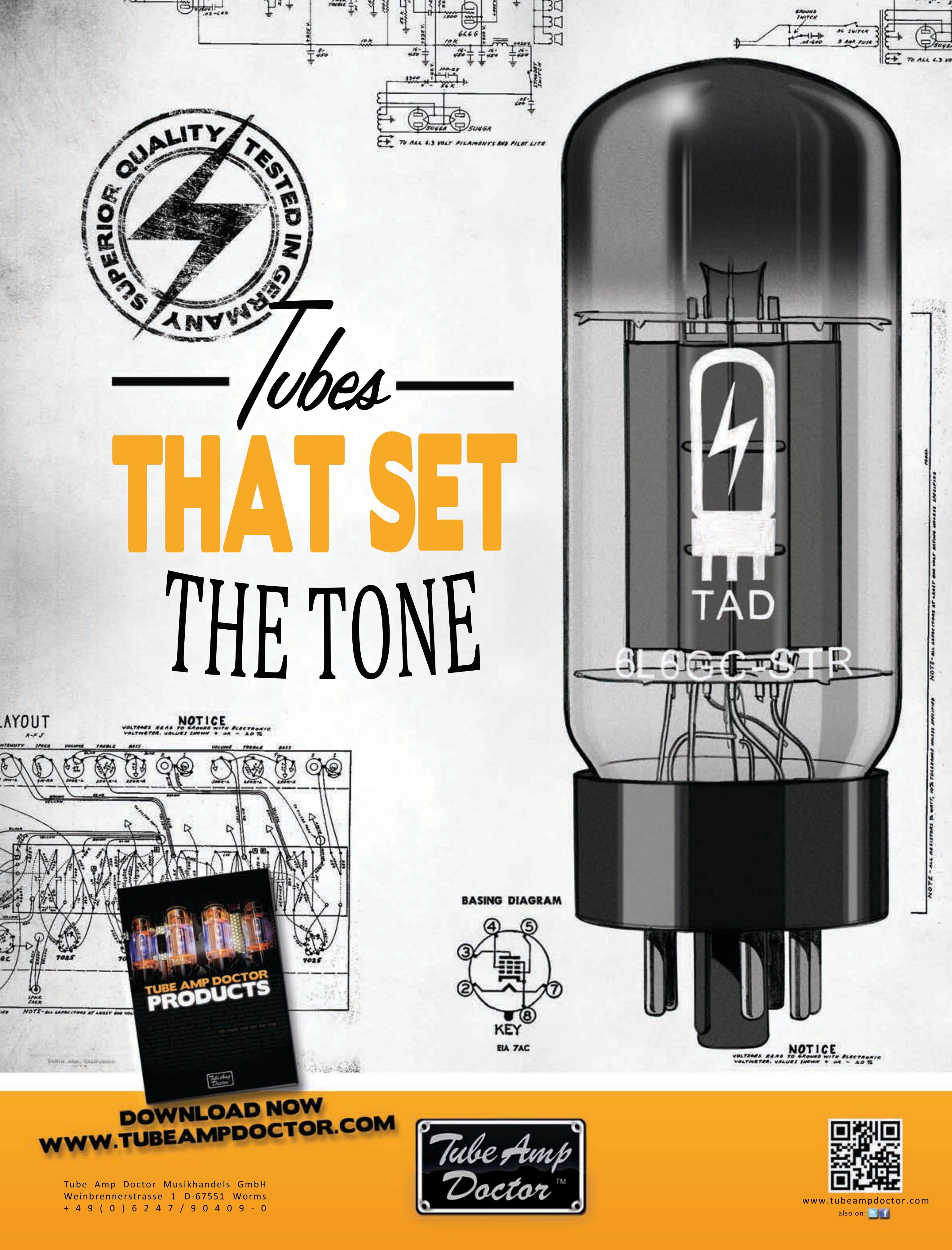
Editor's note: Bruce Heran likes to support the DIY community. If you have difficulty with this project and can't determine what is wrong, contact him at gofar99@hotmail.com.

REFERENCE

[1] M. Leibowitz, "Compact Hi-Fi Power Amplifier," *Electronics World*, 1961.

RESOURCE

Oddwatt Audio, oddwattaudio.com.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Deconstructing the SC-OPT

An ideal output transformer for single-ended valve amplifiers

By Pierre Touzelet (France)

In the late 1990s, Aristide Polisois, an Italian audio newcomer, introduced a clever new output power transformer concept for single-ended (SE) valve amplifiers. He called it the self-compensated output power transformer (SC-OPT). The concept's objective was to cancel the annoying DC magnetic flux that occurs in the magnetic core due to the quiescent output power valve's DC current.[1]

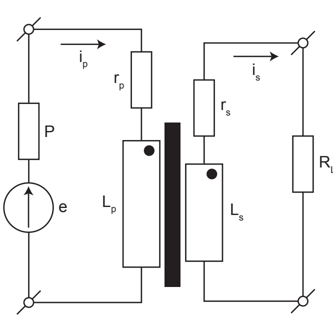


Figure 1: This CO-OPT circuit diagram shows a primary and a secondary inductance.

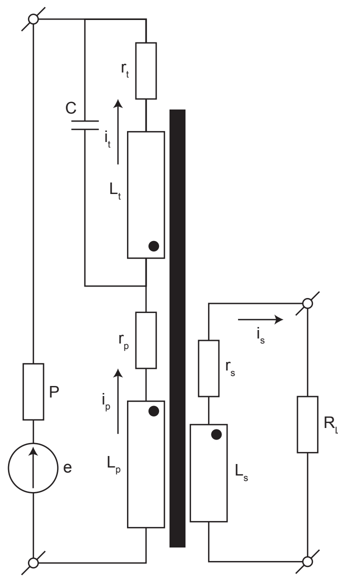


Figure 2: The SC-OPT's circuit diagram shows that the tertiary's inductance is equal to that of the primary.

To resolve this problem in the conventional output power transformer (CO-OPT), an air-gapped magnetic core with a large cross section leading to heavy and expensive output power transformers is used to achieve satisfactory performance.

Polisois's concept uses a tertiary winding, which has the same number of turns as the primary winding but it is wound opposed to the primary on the magnetic core. However, this intuitive, simple solution requires a large shunting capacitor across the tertiary winding to avoid AC cancellation and a loose coupling between the primary and tertiary windings to deliver power into the loading resistor.

In this article, I review how a SC-OPT works, compare it to a CO-OPT, and discuss the influence the shunting capacitor and loose coupling have on low-frequency performances. I provided guidelines and recommendations to achieve a good SC-OPT design with an optimum match to the power output valve. Examples of SE valve amplifiers that use SC-OPT are also provided, demonstrating the interest generated by this concept regardless of the DC-current value.

CO-OPT BEHAVIOR

The CO-OPT has a primary inductance L_P and a secondary inductance L_S (see **Figure 1**). For simplicity, I neglect the leakage inductance between the primary and secondary windings because I am not focusing on its behavior at the high-frequency end, only at the low-frequency end. As a result, the mutual inductance between the primary and secondary windings is:

$$M_{PS} = M_{SP} = \sqrt{L_P L_S} \qquad [1]$$

An AC generator with an electromotive force e and an internal impedance ρ is connected across the terminals of the primary winding. A loading resistor R_L is connected across the terminals of the secondary circuit. Winding resistors r_P of the primary and r_S of secondary are neglected compared respectively to the generator internal impedance ρ and the loading resistor R_L. With these realistic assumptions, the classic set of differential equations describing the CO-OPT behavior is:

$$e = \rho i_P + L_P \frac{di_P}{d_T} + \sqrt{L_P L_S}\frac{di_S}{dt}$$
$$0 = R_L i_S + L_S \frac{di_S}{dt} + \sqrt{L_P L_S}\frac{di_P}{dt} \qquad [2]$$

A system described by Equation Set 2 of differential equations behaves like a first-order high-pass filter, having the following corner frequency:[2]

$$f_{CO-OPT,-3dB} \simeq \frac{1}{2\pi}\left(\frac{\rho R_L}{\rho L_S + R_L L_P}\right) \quad [3]$$

Hence, showing that the SC-OPT, under certain conditions, behaves like a CO-OPT, equates to showing that the set of differential equations describing the SC-OPT behavior can be reduced to the one describing the CO-OPT.

SC-OPT BEHAVIOR

Now consider the SC-OPT shown in **Figure 2**. Assumptions made regarding the CO-OPT also apply to the SC-OPT. In addition, assume that the inductance of the tertiary L_T is equal to the inductance of the primary and that the tertiary winding resistor r_T is negligible.

Because there is a loose coupling between the primary and tertiary windings, the mutual inductance between them is:

$$M_{PT} = M_{TP} = -\lambda_{TP}\sqrt{L_P L_T} = -\lambda_{TP} L_P \quad [4]$$

where λ_{TP} is the coupling factor between both windings.

For the same reason, the mutual inductance between the tertiary and secondary windings is:

$$M_{ST} = M_{TS} = -\lambda_{TS}\sqrt{L_S L_T} = -\lambda_{TS}\sqrt{L_S L_P} \quad [5]$$

where λ_{TS} is the coupling factor between both windings.

It's safe to assume that, according to the location of the tertiary on the magnetic core, with $\lambda \leq 1$, we always have:

$$\lambda_{TP} = \lambda_{TS} = \lambda \quad [6]$$

Assuming that the shunting capacitor is large enough to be considered a true short-circuit across the tertiary winding, the set of differential equations describing the SC-OPT behavior are:

$$e = \rho i_P + L_P\frac{di_P}{dt} - \lambda L_P\frac{di_T}{dt} + \sqrt{L_P L_S}\frac{di_S}{dt}$$
$$0 = L_P\frac{di_P}{dt} - \lambda L_P\frac{di_T}{dt} - \lambda\sqrt{L_P L_S}\frac{di_S}{dt}$$
$$0 = R_L i_S + L_S\frac{di_S}{dt} + \sqrt{L_P L_S}\frac{di_P}{dt} - \lambda\sqrt{L_P L_S}\frac{di_T}{dt} \quad [7]$$

Equation Set 7 can easily be reduced to the following simpler one:

$$e = \rho i_P + L_P\left(1-\lambda^2\right)\frac{di_P}{dt} + \left(1-\lambda^2\right)\sqrt{L_P L_S}\frac{di_S}{dt}$$
$$0 = R_L i_S + L_S\left(1-\lambda^2\right)\frac{di_S}{dt} + \left(1-\lambda^2\right)\sqrt{L_P L_S}\frac{di_P}{dt} \quad [8]$$

DISCUSSION

To finalize the above analysis, if $\lambda < 1$ (corresponding to a loose coupling between the primary and tertiary windings), let the reduction factor be:

$$F_R = \left(1 - \lambda^2\right) \qquad [9]$$

We can write:

$$L_P^* = F_R L_P,\ L_S^* = F_R L_S,\ M_{PS}^* = M_{SP}^* = \sqrt{L_P^* L_S^*} = F_R M_{PS} \qquad [10]$$

Substituting Equation Set 10 into 8 demonstrates that Equation Set 8 is strictly similar to the differential equations in Equation Set 2. Hence, the SC-OPT behaves, at low frequency, exactly as the CO-OPT, (i.e., a first-order high-pass filter). But as the inductances of the primary and secondary are reduced, the cut-off frequency at the low-frequency end becomes:

$$f_{SC-OP,-3\,dB} = \frac{f_{CO-OPT,-3\,dB}}{\left(1 - \lambda^2\right)} = \frac{f_{CO-OPT,-3\,dB}}{F_R} \qquad [11]$$

If $\lambda = 1$ (corresponding to a tight coupling between the primary and tertiary windings) then $i_S = 0$ and no power is available to the loading resistor.

OBSERVATIONS

The SC-OPT works exactly as the CO-OPT only if there is a loose coupling between the primary and tertiary windings and if the tertiary's shunting capacitor is large enough to locate the resonance within the tertiary, far below the low-end corner frequency.

Because of the primary and secondary inductance reduction, the output power valve must feature a low-internal impedance to produce a low-end corner frequency value, compatible with hi-fi audio specifications. However, this result must be obtained using a primary inductance that is not too high to preserve the high-frequency end response. With that in mind, power triodes are SC-OPT's natural companions.

A good DC magnetic flux compensation requires a coupling factor λ as close as possible to 1, but values too close to 1 rapidly increase the low-end corner frequency. This shows that the coupling factor's final value must be the result of a compromise between the output power valve's internal impedance and the primary inductance, according to the requested low-end and high-end corner frequencies.

With an appropriate tertiary winding location on the magnetic core, the resulting natural magnetic flux leakage is generally sufficient for a SC-OPT designed to deliver moderate output power (5 to 15 W).

For a SC-OPT designed to deliver larger output power (20 to 100 W), this solution is less efficient and requires a special device Polisois also developed called the "flux escape."

Audiophiles who have listened to SE valve amplifiers equipped with an SC-OPT are typically surprised by their sound clarity and purity. A probable explanation is that the loose coupling between the tertiary and primary windings means that the AC magnetic flux, that cannot pass through the tertiary, is forced to pass through an air gap which, due to its high reluctance in regard to the one of the magnetic cores, strongly improves the SC-OPT's linearity.

The SC-OPT's high-end response can be analyzed using the same method used for the CO-OPT. Classical splitting and overlapping techniques can be used to minimize the leakage inductance between the primary and secondary windings and the globe parasitic capacitance seen across the primary terminals.

Polisois also developed, in collaboration with the Italian engineer Giovanni Mariani, a surprising variation of his concept: the split-core stereo common circuit double-ended transformer (SC-SCC-DET), which uses only one magnetic core for stereo applications.[2,3]

Polisois tested SC-OPTs with moderate and large DC current capabilities in association with his direct coupling modulated bias (DCMB) SE valve amplifier to demonstrate his concept's validity and its ability to cope with any DC current value.

For moderate DC current, the best choice is the well-known 2 × 15-W Simplex valve amplifier, which uses the 6SN7 GT valve in the driving section and the big Russian 6C33C as the output power valve. Under these conditions, the quiescent DC current going through the SC-OPT is 250 mA. However, this DC current value is already a challenge for an air-gapped magnetic core solution.

For a large DC current, the best choice is the King valve amplifier 2 × 45 W, which uses the same driving section as the Simplex, but it has three big Russian 6C33Cs in parallel for the output power valve. (Refer to www.polisois-audio.com for more information.) Under these conditions, the quiescent DC current going through the SC-OPT is 750 mA. Imagine, with this large a DC current value, what the air-gapped magnetic core solution should be.

In both cases, the performance was excellent as well as the sound quality, which was always characterized by its clarity and purity.

OBJECTIVES

In this article, I have demonstrated that the SC-OPT developed for SE valve amplifiers works exactly (under certain conditions) as the CO-OPT. We have also clarified the influence of the shunting capacitor across the tertiary and the loose coupling between the primary and secondary windings. Design guidelines have been established and defined to achieve excellent performances.

Polisois's concept addresses, without difficulty, any quiescent DC value, opening the field of powerful SE valve amplifiers not possible with the classic air-gapped magnetic core solutions. This last feature, added to the remarkable clarity and purity of their sound, should convince DIY audiophiles who prefer SE valve amplifiers to use this simple and clever new output power transformer concept. aX

REFERENCES

[1] A. Polisois and P. Touzelet, "The Self-Compensated Output Power Transformer (SC-OPT) Theory and Properties," Convention Paper 6346, 118th AES Convention, 2005.

[2] A. Polisois and G. Mariani, "The Self-Compensated Audio Transformers for Tube and Solid-State Single-Ended Amplifiers," Convention Paper 6831, 120th AES Convention, 2006.

[3] A. Polisois and P. Touzelet, "Direct Current Offset and Balance for Audio Transformers Used with Paralleled Tubes or Solid-State Devices," Convention Paper 7151, 122nd AES Convention, 2007.

questions and answers An Interview with Adam Clarkson

Tube Amplifier Design

Brothers collaborate on a new audio system with a classic look

SHANNON BECKER: Tell us a little about your background. Where are you located? Where and what did you study?

ADAM CLARKSON: I have been working in product development for the past 10 years in Franklin, IN, for my father's company, Agri-Tronix, where we manufacture agricultural electronics and also professional tournament fishing scales. Yes, tournament fishing is a sport and we provide the scales necessary to decide the winner. I attended Indiana University for two years after high school where I studied graphic design and pre-engineering. After my brief tour of college life, I bounced around from bartending job to bartending job before deciding to come to work for my father. It's truly been a blessing to work for the man I most admire, I've learned more from him than I could ever describe. My brother, Ben, began working with me about two years ago after he graduated from the University of Southern Indiana with a Bachelor's degree in Fine Arts.

SHANNON: What is your current occupation?

ADAM: Sales, marketing, project manager, graphic designer, technician, and anything else that needs to be done.

SHANNON: How did your interest in audio electronics develop?

ADAM: I've always been interested in electronics and always loved good audio. There was an allure to vacuum tubes, so we started experimenting and we really think that we've created something special.

SHANNON: How did you and your brother Ben get involved with Kickstarter? What about it appealed to you?

ADAM: The ClockOS was our first kickstarter project. I had a friend who had decent success on Kickstarter, and I thought, "Hey I could do that." So we set out to come up with a project to put on Kickstarter and test the waters. We came up with the ClockOS, which had mild success. We learned so much from doing that project. And, we did some things wrong with that project that really held it back from being great. The idea of Kickstarter is really neat, and I think that a lot of people want to just help out. They want to be involved in something new, get in on the ground floor, so to speak. Even though the backers are *not* investing in the company, they still have this desire to be involved. The all-or-nothing funding was the one thing that really convinced us to go with them over the other crowdfunding sites like indiegogo.com.

SHANNON: In what stage of development is the ClockOS?

ADAM: Unfortunately, this project had to be retired as the manufacturing cost was just way too high. The machine shop that originally quoted the aluminum for us came back after the project ended with a price that was three times as high. We then had to scramble to find a new shop and what we saved in money, we sacrificed in quality. We spent many weekends reworking the machined parts, hand polishing and surface prepping each one to a show quality finish. If you added our time to the cost of the ClockOS project (which any good business owners should) we would have lost money on the ClockOS project. We learned from our first project and took it to the BlueTube amplifier to make sure it was a success. It worked.


Brothers, Adam (left) and Ben Clarkson, are working on BlueTube Audio's classic wooden speakers designed to match their new vacuum tube amplifier.

SHANNON: Share some details about your company, BlueTube Audio. What made you and Ben go into business together?

ADAM: BlueTube Audio's niche is "functioning art." We want to design products that are art pieces but have function in modern society. Our new project is the BlueTube Audio vacuum

BlueTube Audio's new vacuum tube amplifer comes with two handcrafted wooden speakers.

The back of the BlueTube Audio amplifier is clearly labeled for easy use.

The amplifier's power button emits a soft blue glow when the device is on.

The amplifier's vacuum tubes provide the modern-day amplifier with some old-world charm.

tube amplifier. As for our partnership, we were already working together and, in my opinion, we make a great team. We are brothers so we do have our battles, they are usually small though, and we always work through them.

SHANNON: Describe the BlueTube Audio vacuum tube amplifier and its current status.

ADAM: We decide to put the amplifier on Kickstarter as it really is a good platform for raising funds for your initial production run. We needed to have custom sheet metal plates punched, powder coated, and silkscreened for the back panels. The front panels are made of brushed stainless steel and require specialized machinery to punch and cut them. The internal chassis is really a marvel of sheet metal bending that I designed, and I am pretty shocked the sheet metal shop said they could bend them.

We have also three separate PCBs in the unit. The main board is populated with the tube sockets, the capacitors, the resistors, and the other fun components that are required for a vacuum tube amplifier. The secondary PCB has all the inputs and DC voltage circuitry on it. This board also has the USB port attached with smart charger circuitry.

The circuitry automatically detects the proper voltage and current for your USB device, whether it's an Samsung Galaxy or an iPad, we can give the device all the power it wants. This secondary PCB also has all the Bluetooth circuitry attached to it. The third board is a small one, but it is connected to the input selector switch and distributes the input signal to the amplifier and then out to your speakers.

All these things require quantity orders that we would not have been able to fund without the Kickstarter program. Now that we have the startup capital, we can order more parts than we need and actually have inventory on the shelves—about 10 times as much inventory in some cases. Currently, production of the first units is in full swing, and we are constantly ordering parts.

SHANNON: The amplifier's old-world look camouflages some very modern audio electronics. Why choose this combination?

ADAM: Because it looks awesome and sounds great! I love the look of the old-time tombstone radios and the handcrafted woodwork. The warm glow of the vacuum tubes. The reflection of the glass and metal. We don't put plastic on our units because plastic looks cheap. Ben is the woodworker, and he did an amazing job handcrafting these units.

As for the new world technology, well, we don't really want to sacrifice our convenience either. Why not have both? Great sound and the convenience of Bluetooth.

SHANNON: Do you have any advice for *audioXpress* readers who are thinking of building their own sound systems?

ADAM: Be careful when working with tube amplifiers. The capacitors can take hours to fully discharge and even when unplugged they can give you quite a jolt. Also, don't be afraid to experiment.

SHANNON: Are you planning any other speaker-related projects?

ADAM: Yes, Bluetooth and stereo. That's all that I can say right now.

SHANNON: Where do you see the audio industry 10 years from now?

ADAM: Much as it is now; however, with the shift to digital in the last few years, there has been some sacrifice of quality. I foresee people crying for better quality. Many people, including myself, love the convenience of having their entire music library in their pocket. But I've noticed that I don't buy albums like I used to. I have the shuffle bug or the skip bug and I don't listen to a whole album through and through like I used to. I guess this isn't really a prediction just a complaint of something that I find missing. I miss the collection of a music library. I miss sitting down and listening to an entire album. I miss the sound of good music and the music sounding good. We're seeing a shift to better things. I just can't say where we will end. *aX*

By Burkhard Kainka (Germany)

FET Amp with Valve Sound

FETs can provide a warm sound

You can make a Class-A field-effect transistor (FET) amplifier sound as good as a valve amp by following the right design principles. This amp may not have particularly high output power but, using standard components, it produces a "warm sound" reminiscent of a valve amplifier.

This design's purpose is not to produce an amplifier that will compete with modern high-quality sound systems in terms of output power and low distortion. It is intended to be more experimental. I used modern FETs in a valve circuit configuration to try and recreate the warm "valve sound" produced by valve amplifiers appreciated by many audiophiles (see **Photo 1**).

To start, it's a good idea to compare a typical single-ended EL84 valve output stage with a modern semiconductor push-pull output amp. The valve amplifier's output stage operates in pure Class-A configuration. Even with the volume control turned all the way down (quiescent) there is still appreciable dissipation in the output stage so the valves will always run hot. An EL84's dissipation could be 12 W so the valves will be running quite hot. By comparison, semiconductor amplifiers are typically designed with a "Class-AB" output stage. Under quiescent conditions, very little power is dissipated in the output transistors. At higher signal levels, the two output transistors operate in push-pull, sharing the load, but this also creates a certain amount of crossover distortion.

The valve operates as a current source. Its output impedance is relatively high so it offers little electrical damping to the speaker cone's movement. The speaker cone's motion is also affected by many other factors including the loudspeaker enclosure's resonant frequency. By contrast, a semiconductor amplifier has a low impedance output stage operating as a voltage source. This configuration leads to much "stiffer" speaker control with effective damping and provides a more controlled, flatter frequency response characteristic to the sound system. This also means the speaker system's individual sound character is suppressed.

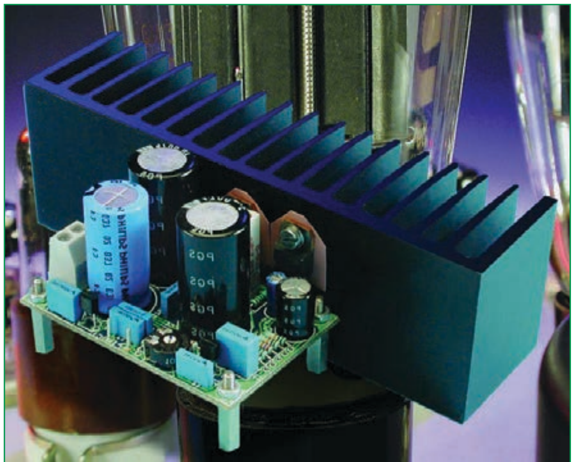


Photo 1: This valve headphone amplifier provides plenty of output power.

The valve's characteristics are not linear but slightly curved. At a low volume, the signal levels are small so the valve operates over a near-linear region of its characteristics. This will provide little output signal distortion. When the volume is increased, the signal swing is larger and the valve's nonlinear nature becomes more apparent, introducing a soft limiting to the output signal. This type of limiting is quite pleasant and is achieved without using any overall negative feedback. A typical Class-AB semiconductor amplifier uses a lot of negative feedback to produce an amplifier with very low levels of signal distortion and low output impedance. When this type of amplifier's volume increases, the output signal increases proportionately until the signal peaks approach the levels of the amplifier supply voltage. Any further increase in signal input will cause "overdrive" when the driver transistors switch off at the signal peaks. This condition occurs suddenly and the resultant signal clipping produces an unpleasant harsh sound. For this type of amplifier, it is important to ensure that it isn't overdriven. By contrast, a valve amp is more forgiving and responds to overdriving in a more "listener-friendly" manner. For this reason, valves are often used in guitar amps where they are deliberately overdriven to produce different sound effects.

THE AMPLIFIER CIRCUIT

The amplifier operates in a Class-A configuration. The design does not use

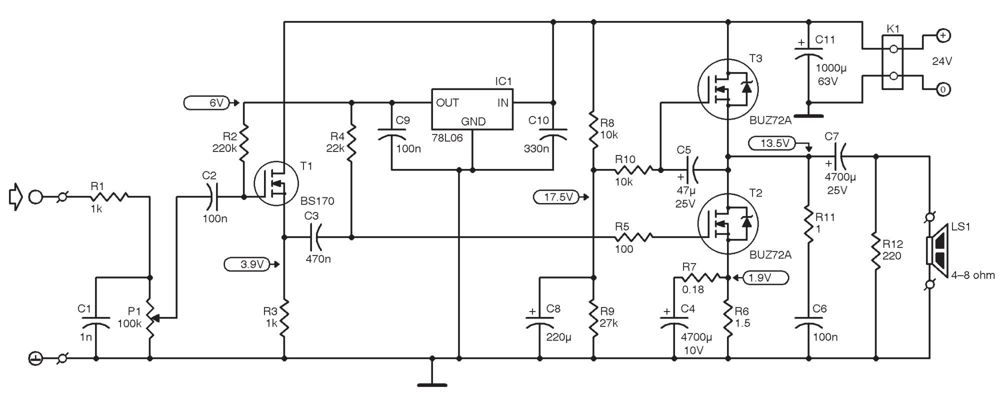


Figure 1: The FET "valve" amp uses few components.

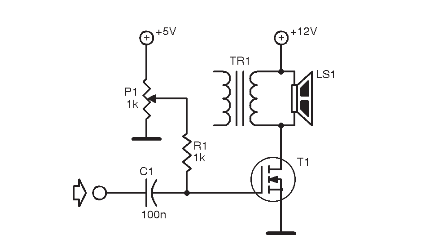


Figure 2: This schematic shows an earlier prototype amplifier.

any overall negative feedback to compensate for the output FET's nonlinear characteristic. This amp's output impedance is quite high to reduce loudspeaker damping and to enable the speaker system's individual acoustic properties to be heard. At the input, R1/C1 acts as a low-pass filter to remove unwanted high-frequency signals. The circuit's first stage consists of BS107 (T1), a small-signal MOSFET, which is used as an input buffer (see **Figure 1**). It provides a high-input impedance and low-output impedance with a voltage gain of about 1. The low-output impedance helps overcome the effects of T2's gate capacitance. T3 operates as a constant current source. It passes DC current while the output signal's AC content from T2's drain is applied across the loudspeaker. The amplifier requires a 24-V input voltage. No setup is necessary with this circuit because the operating point is automatically adjusted. A 6-V voltage regulator is used to derive T1 and T2's gate voltage. The current through the FET is defined by the source resistance value. The quiescent current in T2 is self-regulated to 1.28 A, but the relatively widespread individual FET characteristics can influence this figure.

THE OUTPUT DRIVER

An earlier prototype amplifier was built prior to this project (see **Figure 2**). This amplifier uses just a single vertical metal oxide semiconductor (VMOS) FET per channel. The output transformer acts as a choke. The secondary winding's DC resistance is less than 1 Ω so only a small proportion of the drain current flows through the loudspeaker. A preset is used to adjust the amplifier's operating point. No driver stage is used so the power FET's relatively high-input capacitance means it is can only successfully drive the amplifier at high frequencies by using a low-impedance signal (e.g., from a CD player's headphone output). The sound produced by this simple circuit is comparable to this amplifier. However, the design needed improvement in three main areas.

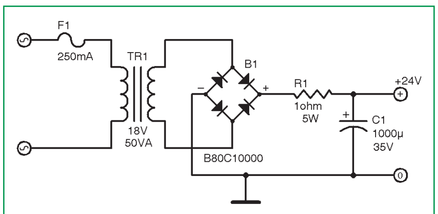


Figure 3: The basic power supply is shown with a series resistor.

The FET amp should be able to connect to normal-impedance loudspeakers without an output transformer. An electrolytic output capacitor would ensure AC coupling to the loudspeaker.

The amplifier's operating point should not require any setup adjustment and must be self-stabilizing. A stabilized gate voltage should be used with some localized feedback from a resistor in the FET source lead.

The input to the amplifier should be compatible with a standard high-impedance line-in signal (1 V_{PP}). The input transistor T1 is configured as a source-follower to act as a buffer. With these requirements in mind, I produced the amplifier circuit shown in **Figure 1**. The diagram shows just one channel. The most obvious difference from the earlier design is the extra power FET (T3) in the output stage. This FET is used as a high-impedance current source and biases the output FET's drain at the supply voltage's midpoint. A potential divider network R8/R9 provides the bias voltage to the T3's gate with an additional 4 V necessary to take into account the FET's gate-source voltage. Capacitor C8 reduces any AC ripple on this reference voltage. C5 maintains a constant gate voltage to T3 during operation. This gives the current source a high-output impedance, which together with the signal amplifying FET's high-impedance output provides the complete amplifier its high-impedance output characteristic. During testing, the amplifier's dynamic impedance was measured at 38 Ω. The output signal to a low-impedance (4-to-8-Ω) loudspeaker is not in the form of a signal voltage but

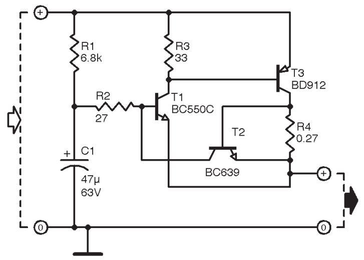


Figure 4: An add-on circuit reduces hum.

rather a signal current. This is unusual for a semiconductor amplifier but it provides the amplifier's characteristic "valve sound." The FET's use as a current source in the output stage instead of the typical impedance-matching transformer means I do not need to compensate for the transformer's frequency response. A suitable transformer or output choke is a specialty item that is not easy to find. A disadvantage of this approach is the increased power consumed by the circuit. The signal amplifier FET (T2) dissipates around 12 V × 1.28 A ≈ 15 W in its quiescent state and the constant current source uses about the same amount. Combined, this produces more than 30 W of energy converted into heat. With this in mind, it's important to ensure that this energy can be safely dissipated. The heatsink should have a minimum 1-K/W or lower thermal resistance. The FET amp can also be run with a higher supply voltage up to around 35 V, providing a larger drain current. In this case, the source resistor will need to be correspondingly reduced in value. Consider this modification if you like the sound produced by this amp and want to experiment a little. The voltage produced across the source lead resistor generates a localized negative feedback and reduces the amplifier's slope and amplification factor without reducing its output impedance. C4 shunts this feedback signal to ground and controls the amplifier's frequency response. The amplification factor at high frequencies is set by resistor R7 (0.18 Ω). To extend the amplifier response down to 30 Hz, the C4 capacitor's value would theoretically need to be increased to 30,000 µF! This modification would not only be expensive but also potentially damaging because it is much easier to overload the amplifier at low (bass) frequencies.

THE POWER SUPPLY

The power supply shown in **Figure 3** can be constructed quite easily. A small amount of mains ripple on the output voltage will be damped by the amplifier's constant current output. A resistor in series with the reservoir capacitor reduces the peak charging current and helps attenuate the the ripple voltage's higher frequency content. The amplifier has a relatively poor 20-dB hum rejection figure. An additional add-on circuit reduces the supply ripple so the output hum is no longer audible. The add-on circuit shown in **Figure 4** consists of a voltage regulator circuit built from discrete components.

The reference voltage is derived from the supply voltage's averaged value. The voltage drop over the regulator is independent of the rectified transformer voltage's value. T1 and T2 are configured to form a Darlington transistor with T3/R4 providing short-circuit current sensing in the collector lead. With T2 mounted on a sufficiently big heatsink, the regulator is short-circuit proof. The regulator voltage drop is about 1.9 V, so during normal operation, the power dissipation should be less than 2.5 W. The current limit is set to around 1.9 A. A short circuit at the output will produce approximately 45-W power dissipation by the circuit. For testing, I used a 50-VA toroidal mains transformer with two 18-V secondary outputs together with a 10,000-µF (35-V) reservoir capacitor. With no additional filtering, a 800-mV_{PP} ripple voltage was measured on the output. To reduce this ripple, a higher voltage is necessary, so R1 (6.8 kΩ) produces an additional 1-V voltage drop across the regulator.

It is also necessary to consider the thresholds of transistors T1 and T2. In practice, it is possible that the T1's H_{FE} could cause the voltage to be too high or too low. R1 will need to be changed to compensate. (This is the only disadvantage of this simple solution.) Transistor T3 limits the output current by controlling T1's base voltage so the output current reaches a maximum value defined by the voltage drop across R4. A STMicroelectronics BD912 transistor is used for T2. This transistor can handle 15 A, so a higher maximum output current can be safely selected, if necessary, by reducing R4's value. The maximum current for T3 (a BC639 transistor) is 1 A (1.5-A peak).

Under no-load conditions (with the voltage at approximately 27 V) or a sudden output short-circuit, resistor R2 limits the current through T3 to 1 A. Capacitor C1 is discharged and the power dissipation in R2 remains small.

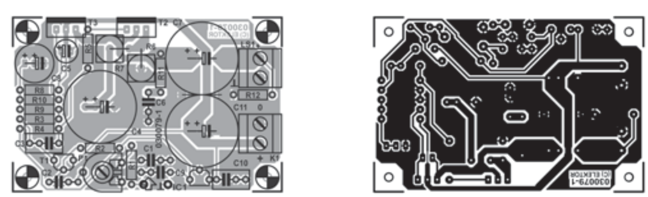


Figure 5: The PCB layout is shown without the hum suppressor.

Technical Data

(Supply Voltage 24 V_{DC}, $I_{T2/T3}$ ≈ 1.28 A)

Amplification factor	at 10 mV_{IN}	13
Bandwidth	at 0.1 W	83 Hz to 155 kHz
Damping factor		0.21 (!)
Efficiency	(4 W/8 Ω)	13%
Input sensitivity	P = 4 W/8 Ω	0.47 V
Output impedance		38 Ω (approximately)
P_{MAX}	8 Ω, 10% THD+N, 1 kHz4 W (sine)	
P_{MAX}	8 Ω, < 20% THD+N, 1 kHz5.5 W (music)	
Signal-to-noise ratio	1 W/ 8 Ω	89 dB (A)
Signal-to-noise ratio	1 W/ 8 Ω, B = 22 kHz	85 dB
THD+N	1 W, 8 Ω/ 1 kHz	4.2%
THD+N	0.1 W, 8 Ω/ 1 kHz	1.3%

COMPONENTS LIST

Capacitors
- C1 = 1 nF
- C2, C6, C9 = 100 nF
- C3 = 470 nF
- C4 = 4,700 µF, 10 V (radial, maximum diameter 18.55 mm, lead pitch 5 mm or 7.5 mm)
- C5 = 47 µF, 25-V
- C7 = 4,700 µF, 25 V (radial, maximum diameter 18.55 mm, lead pitch 5 mm or 7.5 mm)
- C8 = 220 µF, 25 V (radial, lead pitch 2.5 mm or 5 mm)
- C10 = 330 nF
- C11 = 1,000 µF, 63 V (radial, maximum diameter 18.55 mm, lead pitch 5 mm or 7.5 mm)

Miscellaneous
- K1, LS1 = two-way PCB terminal block, lead pitch 5 mm
- Heatsink, R_{TH} < 1 K/W

Resistors
- R1, R3 = 1 kΩ
- R2 = 220 kΩ
- R4 = 22 kΩ
- R5 = 100 Ω
- R6 = 1 Ω5, 5 W
- R7 = 0 Ω18, 5 W
- R8, R10 = 10 kΩ
- R9 = 27 kΩ
- R11 = 1 Ω
- R12 = 220 kΩ
- P1 = 100-kΩ preset

Semiconductors
- T1 = BS170
- T2, T3 = BUZ72A
- 1C1 = 78L06

CONSTRUCTION

The hum suppressor is not included in the amplifier's PCB layout (see **Figure 5**). The large-value electrolytics are mounted vertically on the board to ensure that their case size and lead spacing will fit. This also applies to the power resistors. Before any components are fitted, solder the wire link between C7 and C11. Next, fit all the low-profile components (e.g., the standard resistors, small capacitors, preset resistor, solder pins, and connection blocks). Then, fit the large upright components (e.g., the electrolytic capacitors and power resistors). Finally, the two power FETs can be soldered into place, but not before the heatsink has been fitted to the PCB with a suitable bracket. This ensures that mechanical strain will not be put on the FET leads and joints. Use electrical insulators and heat-conducting paste to ensure that the FETs are fitted to the heatsink. Once the components have been fitted and all the soldered joints have been carefully inspected, the amplifier can be tested. The voltage levels shown on the circuit diagram should help during testing. However, power FETs are produced with fairly large tolerances on their characteristics so the voltage levels shown should only be considered approximate values.

IN USE

The technical data shows that a Class-A amplifier's output power is not particularly high. Theoretically, it should be possible to produce an output power that is about 25% of the quiescent power dissipated in the amplifier. But in practice, it's a little bit less. This amp is probably not the best choice for a sound system if you are planning a big party, but it does produce a sweet sound with the volume control set around its midrange. The soft limiting characteristic ensures that even at maximum volume the sound is not at all unpleasant. At low-volume settings, it is distortion-free with a good transparent tone.

Overall, the sound produced has a full and soft character, truly reminiscent of a valve amplifier. Any amplifier's sound quality is subjective and depends on many factors, not the least being the quality of the speakers connected to the output. In many cases during testing, I found the same speakers produced a more pleasant sound with this amplifier than when they were connected to a conventional hi-fi amplifier. *aX*

Editor's note: This article first appeared in Elektor*, November 2003.*

By Vance Dickason (United States)

Scan-Speak's New 12" Subwoofer

The newest addition to the Revelator line offers a generous feature set

Photo 1: The 32W/4878T00 is Scan-Speak's newest 12" subwoofer.

I recently examined the 32W/4878T00, a new 12" subwoofer from high-end driver manufacturer Scan-Speak (see **Photo 1**). Over the years, Scan-Speak has become known for its midwoofers and tweeters. Its products can be found in a large percentage of the high-end loudspeakers on the market over the last 40 years. Having used Scan-Speak's drivers in designs for some of my consulting business customers, I found it also makes some excellent subwoofers. Currently, Scan-Speak has two Discovery line subwoofers, the 10" 26W/4558T00 and the 12" 30W/4558T00, plus a 10" Revelator subwoofer, the 23W/4557T00/02. The new 32W/4558T00 represents its second addition to the Revelator subwoofer line and, from what I was told, the first production run was entirely sold out!

The 32W/4878T00 has a generous feature set that includes a proprietary nine-spoke cast aluminum frame that is completely open below the spider-mounting shelf. Other features include the incorporation of a stiff flat 12" cone that uses a paper sandwich formulation with a unique, patented foam-fill technology that is stiff and light, an 85-mm hard paper dust cap, nitrile butadiene rubber (NBR) surround, and a 7"-diameter flat cloth spider that has the lead wires woven into the body of the spider (damper).

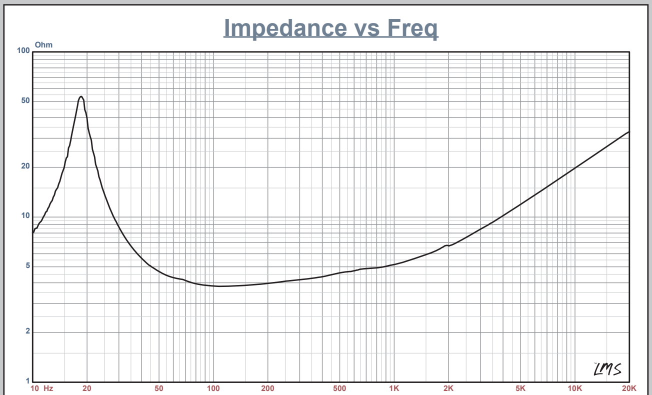


Figure 1: Scan-Speak 32W/4878T00 subwoofer 1-V free-air impedance plot

The 32W/4878T00 is driven by a 75-mm diameter (3") voice coil wound with a round wire on a paper-reinforced vented titanium former. The motor system powering the cone assembly utilizes a 25-mm thick, 175-mm diameter ferrite magnet sandwiched between a polished 8-mm thick front plate and a polished and shaped T-yoke that incorporates a 36-mm diameter pole vent. This motor incorporates the Scan-Speak symmetrical drive (SD)—which was originally patented in 1973—motor system that uses shaped gap parts and copper shorting rings. Additional cooling is provided by the nine large 50-mm × 33-mm "window" vents formed by the frame spokes and located below the spider mounting shelf enabling air to flow across the front plate and exposed voice coil. Last, the braided voice coil lead wires terminate to a pair of gold terminals.

I began characterizing the new 32W/4878T00 12" with the LinearX LMS analyzer and VIBox. I generated both voltage and admittance (current) measurements in free-air at 1, 3, 6, 10, 15, 20, and 25 V. I used the measured Mmd provided by Scan-Speak (an actual physical cone assembly measurement with 50% of the surround and spider removed) rather than a single 1-V added (delta) mass measurement. Note that this multi-voltage parameter test procedure includes heating the voice coil between sweeps for progressively longer periods to simulate operating temperatures at that voltage level (raising the temperature to the third-time constant). I further processed each woofer's 14 sine wave sweeps with the voltage curves divided by the current curves to produce impedance curves. I used the LEAP phase calculation routine to generate the phase curves. I then copied and pasted the impedance magnitude and phase curves plus the associated voltage curves into the LEAP 5 software's Guide Curve library. I used this data to calculate parameters using the LEAP 5 LTD transducer model. Because almost all manufacturing data is produced using either a standard transducer model or the LEAP 4 TSL model, I also generated LEAP 4 TSL model parameters using the 1-V free-air that can also be compared with the manufacturer's data. **Figure 1** shows the 32W/4878T00 1-V free-air impedance plot. **Table 1** compares the LEAP 5 LTD and LEAP 4 TSL T/S parameter sets for the 32W/4878T00 driver samples with the Scan-Speak factory data.

Using the Scan-Speak subwoofer's comparative data in **Table 1**, you can see that all four parameter sets for the

	TSL Model		LTD Model		Factory
	Sample 1	Sample 2	Sample 1	Sample 2	
F_S	18.3 Hz 17.1 Hz17.6 Hz 16.4 Hz18 Hz				
R_{EVC}	3.053.063.053.063.1				
Sd	0.0523	0.05230.0523		0.0523	0.0523
Q_{MS}	6.155.67		5.37 5.25		7
Q_{ES}	0.370.330.350.330.33				
Q_{TS}	0.350.320.330.310.32				
V_{AS}	196.4 ltr	223.5 ltr	214.3 ltr	244.8 ltr	207.5 ltr
SPL 2.83 V	87 dB	87.1 dB	87 dB 87 dB		90 dB
X_{MAX}	14 mm	14 mm 14 mm		14 mm14 mm	

Table 1: Data for the Scan-Speak 32W/4878T00 subwoofer

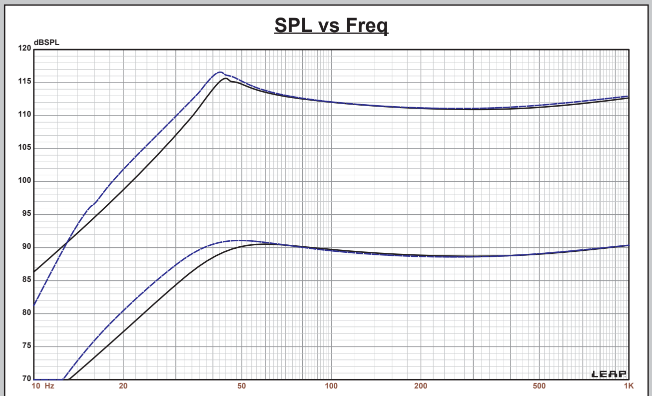


Figure 2: Scan-Speak 32W/4878T00 computer box simulations (black solid = sealed at 2.83 V; blue dash = vented at 2.83 V; black solid = sealed at 48 V; blue dash = vented at 50 V)

two samples were reasonably similar and correlated with the factory data, with the exception that the Scan-Speak data quotes a somewhat larger SD and about 3-dB greater efficiency. Following my normal protocol for Test Bench testing, I used the sample 1 LEAP 5 LTD parameters and set up two computer box simulations, one in a 1.75-ft^3 Butterworth-type sealed enclosure with 50% fill material (fiberglass) and a second vented box quasi third-order Butterworth (QB3) alignment in a 2.91-ft^3 box with 15% fill material and tuned to 21 Hz.

Figure 2 shows the results for the Scan-Speak 32W/4878T00 in the sealed and vented enclosures at 2.83 V and at a voltage level sufficiently high enough to increase cone excursion to X_{MAX} + 15% (16.1 mm for 32W/4878T00). This resulted in a F3 of 37 Hz (–6 dB = 30.3 Hz) with a QTC = 0.67 for the 1.75-ft^3 closed box and a –3 dB for the 32 Hz (–6 dB = 30 Hz) QB3 vented simulation. A larger extended bass shelf (EBS), a 4.9-ft^3 enclosure tuned to 18.5 Hz would have produced an F3 of 26 Hz and F6 of 21.5 Hz. Increasing the voltage input to the simulations until the approximate X_{MAX} + 15% maximum linear cone excursion point was reached resulted in 115.5 dB at 48 V for the sealed enclosure simulation and 116.5 dB with a 50-V input level for the larger vented box. **Figure 3** and

Figure 4 show the 2.83-V group delay curves and the 48-V/50-V excursion curves.

Klippel analysis for the Scan-Speak 32W/4878T00 12" woofer produced the Klippel data graphs shown in **Figures 5–8**. Klippel provided the analyzer and Patrick Turnmire of Red Rock Acoustics performed the analysis. Please note, if you do not own a Klippel analyzer and would like this type of data on any transducer, Red Rock Acoustics can provide Klippel analysis. Visit www.redrockacoustics.com for more information.

The Bl(X) curve for Scan-Speak 32W/4878T00 shown in **Figure 5** is broad and symmetrical (with a slight tilt) typical of a driver with substantial X_{MAX}. The Bl symmetry curve in **Figure 6** shows 5-mm Bl coil out (forward) offset at rest, which transitions to a near-zero offset at 10 to 12 mm of excursion; however, you want to ignore this. Because Bl curve has almost no offset at all, the analyzer has difficulty resolving this at small amounts of excursion (0 to 8 mm). The gray area represents the degree of uncertainty in the measurement.

Figure 7 and **Figure 8** show the K_{MS}(X) and K_{MS} symmetry curves for the Scan-Speak subwoofer. Like the Bl curve, the KMS stiffness of compliance curve is very symmetrical, with only a minor offset (see **Figure 7**). The K_{MS} symmetry range curve has a minor 1-mm offset at rest decreasing to 0.3 mm at the driver's physical X_{MAX}. The Klippel analyzer calculated the 32W/4878T00's displacement-limiting numbers using the woofer criteria for Bl (XBl at 70%). The Bl dropping to 70% of its maximum value is

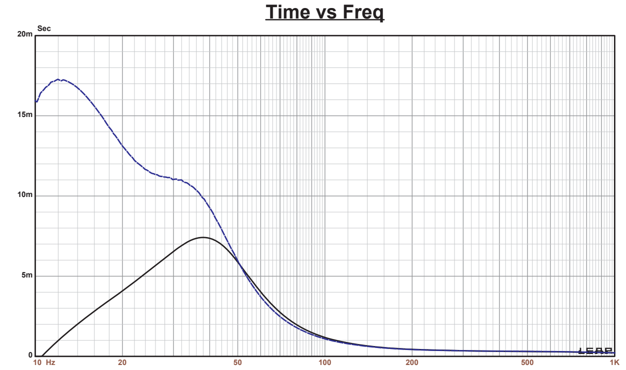


Figure 3: Scan-Speak 32W/4878T00 group delay curves for the 2.83-V curves in Figure 2

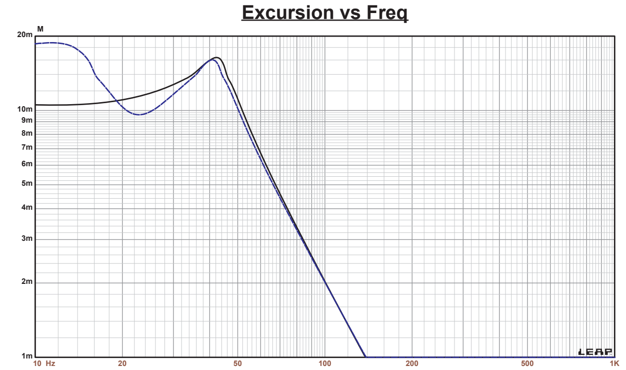


Figure 4: Scan-Speak cone excursion curves for the 48- and 50-V curves in Figure 12

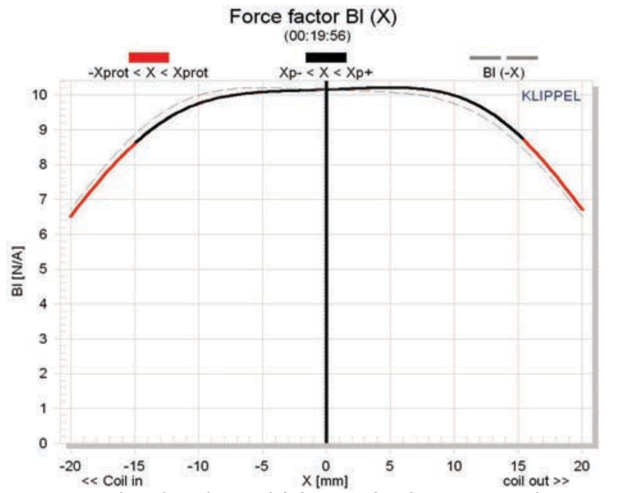


Figure 5: Klippel analyzer Bl (X) curve for the Scan-Speak 32W/4878T00

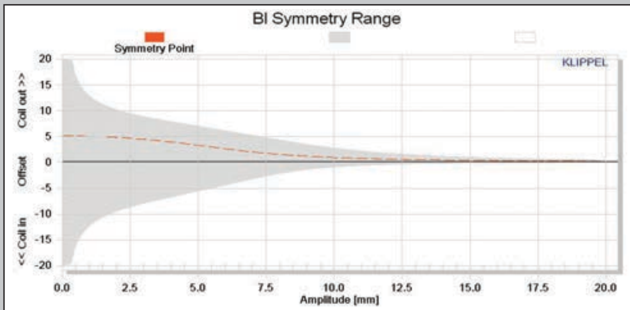


Figure 6: Klippel Analyzer Bl symmetry range curve for the Scan-Speak 32W/4878T00

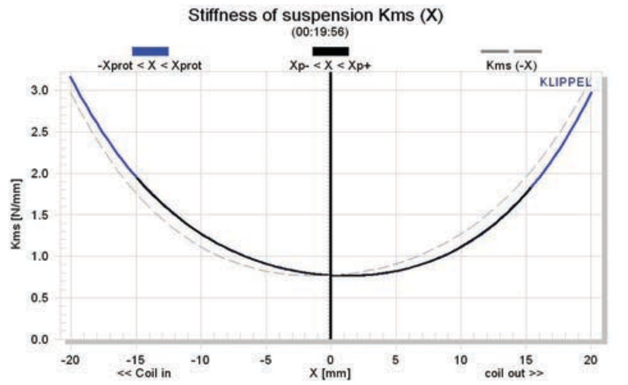


Figure 7: Klippel analyzer mechanical stiffness of suspension K_{MS} (X) curve for the Scan-Speak 32W/4878T00

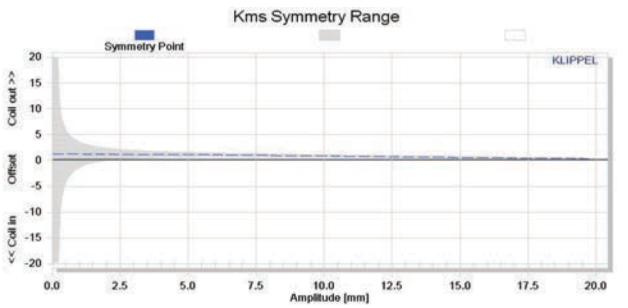


Figure 8: Klippel analyzer K_{MS} symmetry range curve for the Scan-Speak 32W/4878T00

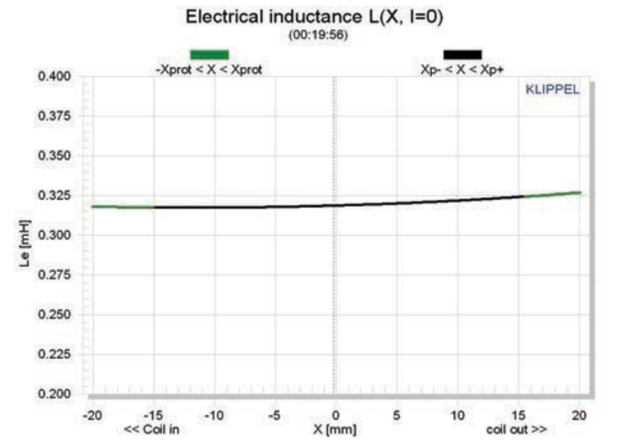


Figure 9: Klippel analyzer Le(X) curve for the Scan-Speak 32W/4878T00

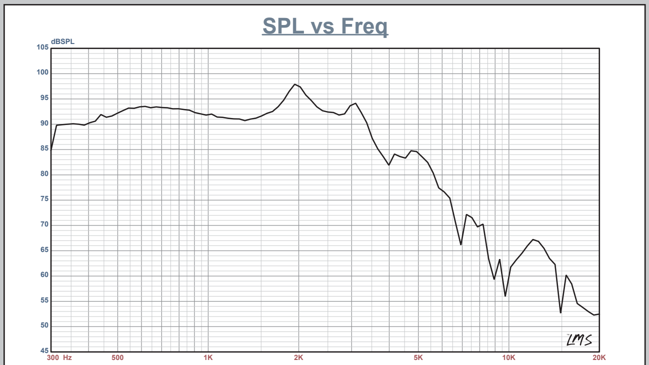


Figure 10: Scan-Speak 32W/4878T00 on-axis frequency response

equal to 14.9 mm. This number is somewhat greater than the physical 14-mm X_{MAX} for this driver for the prescribed 20% distortion level, which is the criterion for subwoofers. For the compliance, XC at 50% C_{MS} minimum was 12.3 mm (1.7 mm less than this driver's physical X_{MAX}), which means that for the 32W/4878T00 subwoofer, the compliance is the more limiting factor for achieving the 20% distortion level.

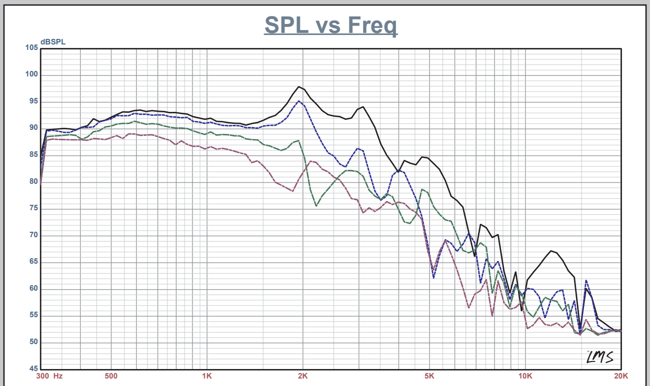


Figure 11: Scan-Speak 32W/4878T00 on- and off-axis frequency response

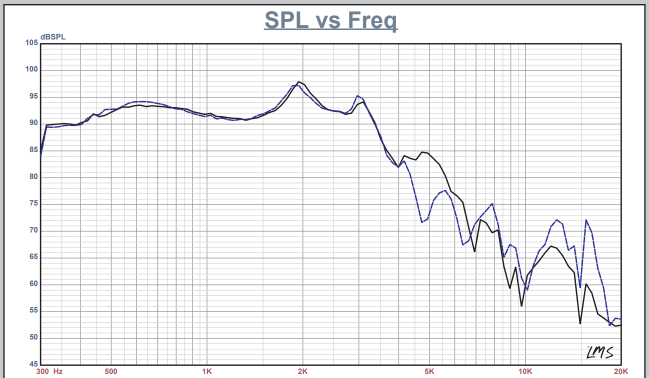


Figure 12: Scan-Speak 32W/4878T00 two-sample SPL comparison

Figure 9 shows this transducer's inductance curve Le(X). Motor inductance will typically increase in the rear direction from the zero rest position and decrease in the forward direction as the voice coil moves out of the gap and has less pole coverage; however, that doesn't happen here. There is almost no inductance variation from full-in to full-out travel, which is the goal. It's easy to see the benefits of the Scan-Speak symmetrical drive motor. Delta inductance over the full range of motion is only 0.01 mH, which is outstanding.

After the Klippel analysis, I mounted the driver in a large enclosure filled with foam damping material with a 15" × 15" baffle area and used the LMS gated sine wave technique to measure the Scan-Speak 12" SPL on- and off-axis. **Figure 10** provides the on-axis response measured 300 Hz to 20 kHz at 2.83 V/1 m. The response is smooth out to the breakup mode at 2 kHz. **Figure 11** shows the on- and off-axis to 45°. Although this is a subwoofer, it could be used in a three-way configuration with a low-pass crossover frequency as high as 1.2 kHz or so to a midrange driver. Finally, **Figure 12** provides the two-sample SPL comparison showing, as expected from Scan-Speak, the drivers to be well matched.

Next, I used the Listen SoundCheck analyzer to perform distortion analysis. As usual, I dispensed with time-frequency analysis for subwoofers as the data is not really significant below 100 Hz. For distortion measurements, I set the voltage level with the driver mounted in an enclosure with a 14" × 30" baffle and increased it until it produced a 1-m SPL of 94 dB (1.4 V), which is my SPL standard for home audio drivers. I made the distortion measurement with the microphone placed near-field (10 cm) and the woofer mounted in the enclosure. **Figure 13** shows the plot for the 12" Scan-Speak subwoofer. There are actually two plots, the top graph is the standard fundamental SPL curve with the second- and third-harmonic curves, and the bottom graph shows the second- and third-harmonic curves, plus the THD curve with an appropriate x-axis scale. Interpreting the subjective value of conventional distortion curves is almost impossible; however, looking at the relationship of the second- to third-harmonic distortion curves is of value.

As can be inferred from the data, this is another well-crafted transducer from the group at Scan-Speak. For more information, visit www.scan-speak.dk. *aX*

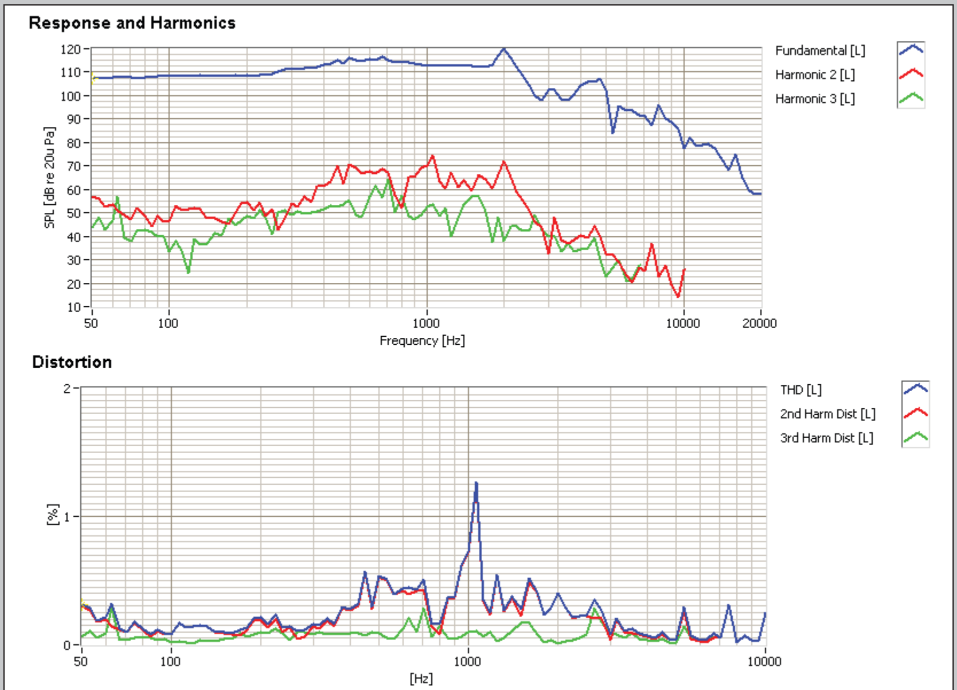


Figure 13: SoundCheck distortion plots for the 32W/4878T00

1923–2013 **Edward T. Dell, Jr.**

Tribute to Ed Dell

Edward T. Dell, Jr.

When Edward T. Dell, Jr., founder and former *Audio Amateur* publisher, passed away in February, editors at *audioXpress* asked themselves this question: How do you celebrate the life of a man who single-handedly did more to foster the audio construction hobby than anyone else?

We asked longtime contributors to submit essays about Dell, whose many publishing achievements included making *audioXpress* the go-to audio technology authority before he sold his company's assets—which included *audioXpress* and *Voice Coil* magazines—to the Elektor publishing group in 2011.

Here we share reflections on the man who, shortly before his retirement at 88, summarized for interviewer Jan Didden the passion that fueled a long publishing career dedicated to DIY audio: "I wonder how things work. That curiosity has been the basis of most of what I did in my life."

If you would like to share your comments about Ed's legacy with *audioXpress* readers online, please visit our Facebook page at www.facebook.com/AudioAmateur.

Minister, Mentor, Intellectual, and Friend

By Gary Galo (United States)

Like so many in the audio community, I was saddened to learn of the death of my friend and mentor Edward T. Dell, Jr., in late February, just two weeks after his 90th birthday. Ed was the founder and longtime editor and publisher of *Audio Amateur* magazine and its peripheral publications and successors.

Not initially destined for a career in audio, Ed Dell's undergraduate education was at Eastern Nazarene College in Quincy, MA, where he earned a BTh and a BA in History. He later completed a MDiv degree at Episcopal Divinity School in Cambridge, MA, and became an ordained Episcopal clergyman. In the early 1960s, he joined the editorial staff of *The Episcopalian* magazine, where he held various editorial positions until 1974.

Running parallel to his career in the Episcopal church was a passion for music that, as it did for many of us, fueled his interest in audio. While living in Swarthmore, PA, he developed a friendship with his neighbor, J. Gordon Holt, founder of *Stereophile* magazine. In 1966, Holt designated the winter issue a "Special Construction Issue." The entire magazine was devoted to a lengthy article by Ed titled "The Brute—A Super-Amplifier for the Do-It-Yourself Perfectionist." That article, describing his elaborate remake of the Dynaco Stereo 70 vacuum tube power amplifier, appeared at a time when DIY articles on audio equipment were few and far between in mainstream publications. There were occasional offerings in magazines (e.g., *Audio* and *Popular Electronics*) but little else, so one would have expected *Stereophile*'s "Special Construction Issue" to be a huge success, having filled a major void in the audio press. Well, nothing could have been further from the truth, and the "Letters" section of the next issue was dominated by correspondence from displeased readers.

Their comments included: "I have just received the 'Winter Construction Issue.' I can hardly wait for my subscription to expire," and "I was so pleased with your 'Special Construction Issue' that I burned it, page by page."

Another reader wrote: "Are you people nuts or something? Here I sit, for unending month after month, waiting for your next batch of equipment reports and record reviews, and what do I get for my patience? A whole issue aimed at the solder-and-spaghetti crowd." This reader really identified the root of the problem, which was *Stereophile*'s erratic publication schedule. When and if the next issue finally arrived, readers wanted equipment reviews, not construction articles, and Holt assured them that this would be the case, henceforth.

Ed Dell published the first edition of *The Audio Amateur* in 1970. The magazine catered to audio construction hobbyists.

But Ed was convinced there was an untapped market for a magazine devoted to DIY audio (Holt agreed), and in 1970 he founded *The Audio Amateur,* leading off with a power amp article by Reg Williamson, an author who would remain a staple of the magazine for years to come. Ed chose the magazine's title carefully—"audio amateurs" were individuals who pursued their interest as an avocation, for pleasure and not for profit.

The word "amateur" in no way implied substandard or inferior work—far from it. Like those involved in the field of amateur radio, Ed believed that the work of audio amateurs should serve as models for the industry in the excellence of their designs and quality of construction. Throughout the coming decades, Ed would add some of the most-respected names in the audio field to his masthead, including Walt Jung, Nelson Pass and Erno Borbely, to name but a few.

Ed's vision proved to be on target, and after publishing *The Audio Amateur* as a sideline to his "day job" for five years, he moved the entire operation to Peterborough, NH, in August 1975, where it became his full-time occupation. Believing there was sufficient interest in loudspeakers to warrant a separate magazine, he launched *Speaker Builder* in 1980. His timing could not have been better. Within a few years, the PC would revolutionize loudspeaker design, and *Speaker Builder* offered articles at the forefront of this rapidly evolving technology. Ed eventually created a third publication, *Glass Audio*, responding to the increasing interest in vacuum tube audio equipment. In 1996, *Audio Amateur* was renamed *Audio Electronics* and changed from a quarterly to a bimonthly publication. Finally, in response to a changing economic and demographic climate, the three magazines were combined into the single, monthly periodical, *audioXpress,* that we have known for more than a decade.

Without Ed's vision and determination, the DIY audio industry we have come to take for granted would not exist, and literally hundreds of excellent projects and designs would never have come to fruition.

I first met Ed Dell in 1980 at the Audio Engineering Society convention in New York City, after having spoken with him on the phone once or twice. We talked about my writing for his magazines, which ultimately happened, and a friendship developed and continued until the end of his life.

In 1985, my wife, Ellen, and I invited Ed to spend a weekend with us in Potsdam, NY. For the next 15 years or so, he continued to visit us nearly every summer. But, it was during that first visit that we came to know something of the breadth of his educational background and intellect. Ellen is a lifelong Episcopalian, and that became the basis for many interesting conversations between them. He told Ellen about having visited C.S. Lewis early in his tenure at *The Episcopalian*, and gave her a copy of Dorothy Sayers' *The Mind of the Maker*, expressing regret that he never had the opportunity to meet Sayers. Ed recalled how he came to find the Episcopal Church a refreshing alternative to the fundamentalism he had experienced growing up. ("I don't like fundamentalists of any kind," he once told me.) He also mentioned being influenced by the metaphysical views of 20th century philosopher Alfred North Whitehead, who had said, "There are no whole truths; all truths are half-truths. It is trying to treat them as whole truths that plays the devil." Ed was, indeed, someone who spent his life seeking truth, and this permeated everything he did, not the least of which was his work in audio.

Ed was especially fond of our daughter, Michelle, who was 16 months old when he first visited. He enjoyed watching her developing interests as she grew up. Ed was one of the most well-read individuals we have ever met, and as Michelle became an avid reader, he did his best to encourage her. One of her all-time favorite books was James Thurber's *The 13 Clocks*, which Ed brought as a present during one of his visits. Ed was also very interested in poetry, and for a time owned Golden Quill Press, a small business located in Francestown, NH, that published books of poetry. When poetry became Michelle's chosen specialization as an English major at Hartwick College in Oneonta, NY, and later as a graduate student at New England College in Henniker, NH, he and Michelle found yet another avenue for conversation during several visits we made to Peterborough during her college years.

His white hair aside, for much of the time I knew him, Ed always seemed younger than he really was, in both his attitudes and his interests. When the PC began to make inroads in the early 1980s, many members of his generation feared them and ran the other way. Ed had already purchased an Ohio Scientific minicomputer for his business to manage the subscription list and had built a Heathkit terminal for it. When clone boards and cases became available for IBM-style PCs, Ed jumped right in and began building them for his office. In 1985, he started a DIY magazine called *Computer Smyth* (that venture was short-lived, the market was saturated with computer publications). Finally, in early 1986 he asked me, "When are you getting a computer?" Thanks to his prodding, I began researching XT-clone parts and, by early October, I had my first computer up and running (and not a moment too soon, I might add). Ed was still building his own computers, and learning new CAD software, well into his 80s.

"Quiet intensity" is the way I would describe Ed's demeanor. Though generally soft-spoken, he was a man of strong convictions whose mind was always at work. Nothing got by him, and he was one of those rare individuals who spent at least as much time listening as he did talking. Ed greatly enjoyed the company of people and enjoyed bringing them together. One of the most important things he achieved as an audio publisher was fostering relationships between his authors, both informally and for collaborative projects. I once mentioned this to him, and he commented that it was the most rewarding part of his job.

Ellen and I last saw Ed early last summer. We passed through Peterborough on our way to Maine and took him out to lunch, which we all enjoyed. Ed was using a walker, but was still able to get around with help. He was in an assisted-living facility at that point, and had a small stereo system set up in his room, where he was listening to a complete cycle of Mahler symphonies he had recently acquired. After our visit, Ellen noted that, though he was obviously thinking more slowly than in years past, he still had his edge and the characteristic twinkle in his eye (especially when he asked about Michelle). Last December, he was in the hospital, and we phoned him there in early January. We talked about stopping in again this summer on our way to Maine.

Over the past several months, much has been written about Ed Dell's contributions to audio. Ellen and I also remember him as a humanist with a keen intellect and broad-ranging knowledge and interests. Personally, I will always be grateful for his help and encouragement at the very beginning of my long career as a writer. Ed left a lasting impression on everyone who was fortunate to know and work with him. Though we will surely miss him, he has left us an enduring legacy.

Gary Galo, an audio engineer at The Crane School of Music, SUNY, at Potsdam, NY, is an audioXpress *contributor.*

Thoughtful, Intelligent, and Humorous

I spoke often with Ed. I always found him thoughtful with a wide range of interests. He was open and enthusiastic to just about any article dealing with audio. He was generous with his support for the many articles I wrote and encouraged me to write my book, *Testing Loudspeakers.* He had a great sense of humor and once told me one very slightly off-color joke that leaves me laughing every time I recall it.

—Joseph D'Appolito, frequent contributor to Audio Amateur *publications*

Furthering the Art of Fine Audio

By Richard Honeycutt (United States)

On February 25, the audio world lost a great visionary and leader, Edward T. Dell, Jr. I first became acquainted with Ed soon after I graduated from college in 1970. A longtime electronics/speaker/audio hobbyist, I frequently bought parts to feed my habit from McGee Radio in Kansas City, MO. At one point, the parts began arriving with a free magazine: *The Audio Amateur*. I read and thoroughly enjoyed the magazine, and found that it was a quarterly publication created by someone named Ed Dell from New Hampshire.

At that time, I worked for Western Electric as a writer of technical documents for telephone-system engineering. I also wrote in my spare time, my first effort being an article that was accepted for publication by *Audio* magazine, but then never actually published. I subsequently wrote a piece on the acoustics of wood for guitar making and it was published. My acquaintance with *The Audio Amateur* led to my third article—this one a tutorial on microphones—which was published in *The Audio Amateur* in 1972 or 1973 (I have the magazine, but it says 1972, Issue 4, on the front, and the editorial and copyright date indicate 1973.)

Never having understood the concept of "enough things to do," I had opened Ye Musick Shoppe, a small musical instrument shop, and my wife and I published a newsletter, *Ye Musepaper,* as a promotional piece for the shop. We mentioned this in correspondence with Ed, and he asked for a copy, since both our newsletter and *TAA* were created on typewriters and hand-justified. Ed was almost as interested in the process of publication as in the subjects of the articles. Perhaps that is why he was so successful in fostering interest in audio through his expertly crafted magazines.

A self-described dilettante, Ed was more of a hobbyist than what is usually called an audiophile in today's jargon. Although quite interested in the classic audio electronics and speakers, he was passionate about building audio equipment. He once wrote an editorial discussing the importance of hobbies, particularly electronics hobbies, for our national technological competence and even national security. During my third career—this one as a college electronics instructor—his point was clearly driven home for me. My all-time-best two students entered the electronics engineering technology program after having been hobbyists for years: one, a designer/builder/modifier of guitar amplifiers, and the other, an Extra Class ham radio operator. Other students who were equally gifted intellectually and academically never seemed to have the "feel" for electronics that these two longtime hobbyists had.

TAA included articles on all phases of audio including amplifiers, preamps, test equipment, speakers, and microphones. In the late 1970s, Ed noticed a substantial interest in building speakers, and publication of *Speaker Builder* magazine began. This periodical was published eight times per year, and became quite popular. Another category of interest appeared in *The Audio Amateur*, culminating in the 1988 introduction of *Glass Audio,* a magazine devoted to audio equipment using vacuum tubes. Interestingly, within the first few years of *Speaker Builder's* publication, a reader survey showed that audio professionals made up a large proportion of the readership. Ultimately, this realization led to two consequences. The first was the 1987 introduction of *Voice Coil*, a newsletter for speaker professionals. Ed secured the services of prominent speaker-consultant Vance Dickason as editor. Beginning as a simple newsletter, *VC* blossomed into the leading magazine worldwide for speaker professionals. The second outcome of finding out how many subscribers to *The Audio Amateur* and *Speaker Builder* were professionals was a name change from *The Audio Amateur* to *Audio Electronics*, which took place in 2000.

Seeing a need for a single source of supplier information in the speaker and vacuum tube industries, Ed began an annual and a biannual publication: the *Loudspeaker Industry Sourcebook*, and the *World Tube Directory*.

The success of *Voice Coil* led to the introduction of *Multimedia Manufacturer* in 2003. Then, after decades of expanding its offerings, Ed's company, Audio Amateur, consolidated some magazines. *Audio Electronics*, *Speaker Builder,* and *Glass Audio* became *audioXpress*. Publication of *Multimedia Manufacturer* ceased. *Voice Coil* continues to be the premier periodical for speaker professionals.

In 2011, at the age of 88, Ed Dell sold *Audio Amateur* to Elektor International Media, which continues to publish *audioXpress* and *Voice Coil,* as well as *Circuit Cellar,* a monthly magazine (print and digital) covering the topics of embedded hardware, embedded software, electrical engineering, and computer applications.

Ed Dell's many magazines have significantly furthered the art of audio.

Along with his magazine publications, Ed Dell also promoted the hobby and profession of audio by publishing books such as Vance Dickason's *Loudspeaker Design Cookbook* and by maintaining, at various times, a mail-order and online store selling kits, books, test equipment, design and testing software, and specialized components for audio.

In addition to providing continuing education for many longtime audio aficionados, Ed Dell left a lifetime legacy to developing audio enthusiasts and up-and-coming professionals that cannot be overstated. That legacy lives on, but Ed will be sorely missed.

Richard Honeycutt, an engineer, teacher, audio enthusiast, and audioXpress *columnist, is a consultant in acoustics and electroacoustics.*

By Jan Didden (The Netherlands)

I first contacted Ed Dell in the 1970s when I submitted, with great trepidation, an article for publication in *The Audio Amateur*.

But Ed wasn't the stern editor, making go/no-go decisions behind an impressive desk. Ed was a coach, an enabler, and a motivator. He believed in you more than you did yourself, it seemed. But first and foremost, Ed was a communicator. Ed wanted to bring you a good, happy, positive message. That's what he did in the colorful streets of Boston, MA, as a minister, and that is what he did as the editor of *The Episcopalian*.

As luck would have it, he lived across the street from audio engineer and journalist J. Gordon Holt in Swarthmore, PA, in the heydays of Holt's magazine *Stereophile*. In 1969, Ed had rebuilt a famous amplifier of the time, the Dynaco Stereo 70. He was dismayed that the best military-specification equipment the industry could produce was basically destroyed after some defined lifetime, often unused, while consumer equipment failed prematurely because it was being built with inexpensive parts and cost-saving shortcuts. So, in rebuilding the 70, he scrounged Boston's used-parts shops for the very best parts he could find.

He talked Holt into publishing the design in *Stereophile*, and the amplifier schematic graced the centerfold of the next issue. To his consternation, Holt received numerous complaints from readers who were not at all interested in building stuff themselves! That is when Ed decided to start his own publication, dedicated to DIY audio equipment and speakers. Holt loaned him his subscriber list, and *The Audio Amateur* was born—as a quarterly—with the first issue published in 1970.

The magazine continued to prosper and, in time, specialized publications were added, such as *Speaker Builder* and *Glass Audio.* In the 1990s, overhead and mailing costs made that untenable, and Ed united the separate publications again as *Audio Amateur,* and later changed the name to *audioXpress*. In 2004, *Audio Amateur* went online with material in addition to the printed magazine, offering combinations of printed and online subscriptions.

For many years, Ed had been friends with the people at *Elektor*, a do-it-yourself electronics publication based in The Netherlands, swapping advertisements and articles with them. So it was natural that Elektor branched out in the US as *Elektor USA* and acquired Audio Amateur in 2011. Ed, at the age of 88, reluctantly agreed to retire.

As editor and publisher of *Audio Amateur*, Ed was the communicator of positive messages. In its first few decades, he always had an editorial in each issue, never tiring of pointing out that making things with your own hands (and enjoying the fruits of that labor) was highly satisfying. He believed that this was most important for people at a time when many jobs had started to become more boring or irrelevant, if not dehumanizing.

His message must have resonated with his tens of thousands of readers throughout his more than 40-year publishing career. Audio DIY is arguably a tiny part of the grandness of humanity. Yet, I am convinced that Ed has reached out and touched many lives, giving people more self respect and self esteem by motivating them to make things with their own hands and develop their knowledge and experience.

Jan Didden is a longtime contributor of articles to audioXpress *and editor/publisher of* Linear Audio*.*

Publisher, Innovator, and Humanitarian

Back in 1984 or 1985, Gary Galo suggested to Ed that he republish the original *Loudspeaker Design Cookbook (LDC)*, five years out of print by that time. He had to do some searching to find me, as when I self-published the *Loudspeaker Design Cookbook* in 1977 and 1978, my name wasn't featured in the book, mostly because it was originally conceived as a promotional tool for my company, Speaker Research Associates.

After some diligent detective work, he gave me a call and told me he wanted to republish the original *LDC*. My response was that it was five years out of print and needed to be updated. I suggested that he should send me all the back issues of *Audio Amateur* and *Speaker Builder*. Then as I rewrote the book, I would incorporate all the relevant references from his magazines. The magazine references would appear along with the others from the Audio Engineering Society, the Acoustical Society of America, and the Institute of Electrical and Electronics Engineers, which I felt would add some well-deserved credibility to his publications. We agreed and, as they say, the rest is history.

My relationship with Ed was a symbiotic one: Publishing my books and hiring me as the editor of *Voice Coil* certainly contributed to making my career as a loudspeaker engineer possible, and those same publications contributed to the long-term success of Audio Amateur. But beyond that, Ed was a good friend, even though we were only in the same room together maybe two or three times during our 25-year working relationship.

On a more personal note, there is one thing that always comes to mind when I think about Ed, which I believe says a lot about his affable personality. It is a little fridge magnet he sent me in 1997. It was his way of announcing to me the release of the fifth edition of *LDC*. It reads: "We'll drink no wine before its time… IT'S TIME!" It's still in my kitchen, as I'm sure it will remain, until the time comes when someone has to write one of these for me.

The last thing I wish to leave all of you "dear readers" (Ed liked that kind of language) is that I am not certain everyone in the loudspeaker and electronics industry—professionals and DIY persons alike—realizes what a major effect Ed had on us all. I don't think loudspeaker DIY would have ever grown as big as it is without Ed Dell's insight into the importance of creating something yourself and his turning that impulse into a publishing company.

In an *audioXpress* (October 2011) interview, he said, "The act of building is one of the most human activities you can do." As far as loudspeaker engineering professionals go, I can't begin to tell you how many of them I have encountered who have said that they got their start in this challenging technology by reading *Speaker Builder, LDC*, and *Voice Coil.*

Ed, from the bottom of my heart, thank you.

—Vance Dickason, Voice Coil *editor*

By Nelson Pass (United States)

I suppose you could say that if Ed Dell had not been around for the past 40 years, the audio DIY community would have had to create him. I doubt anyone else could have done better.

With *Audio Amateur* magazine, Ed picked up the slack from the decline of kit companies such as Heathkit and Dynaco and kept the DIY enterprise alive and healthy well into the Internet age. For a long time, his audio magazines were almost all there was, and much of the resurgence of ordinary people's interest in audio electronics is owed to his efforts.

I started writing for *Audio Amateur* by accident in 1972, and over 40 years produced about 20 articles for the magazine, most of my best stuff. I never met Ed in person, but I can tell you he was a pleasure to work with.

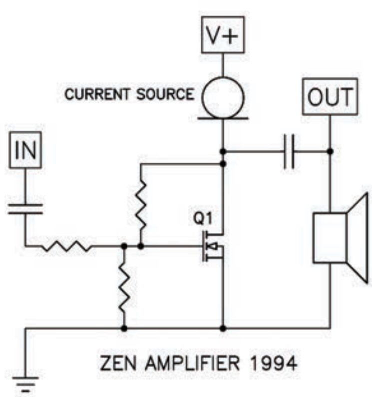
I was asked to include comments and an image or two with this piece, and for sentimental reasons, I chose a simple version of the schematic for the "Zen amplifier" of 1994, which championed the notion of minimalism in amplifier design.

While the idea was met with some derision in audio circles, the intent was to encourage beginning DIYers to get past the intimidation of a first project with something that presented "Class-A performance" with minimal hurdles. I think that was the key thing, and later versions became even simpler (or more complicated) as appropriate to beginners' needs.

Over the years, this amplifier and its variations published in *Audio Amateur* have been built by thousands of amateurs. It lives on today in the form of the "Amp Camp" design used in one-day gatherings in northern California and Europe, where a small group of newcomers build their own power amplifiers in one day.

So I guess it was a good idea, and Ed delivered it to you. He made the world much richer by his efforts, and I feel certain that this is all he would have wanted.

Nelson Pass, who specializes in amplifiers, has been deeply involved in the DIY community since 1973 and has published more than 50 pieces aimed at construction by hobbyists, including the popular single-stage Zen series amplifier.



Here is a simple schematic for the Zen amplifier, which Ed Dell published in *Audio Amateur* to encourage beginning DIYers with a project that presented "Class-A performance" with minimal hurdles.

Gracious, Generous, and Supportive

I first got in touch with Ed Dell in 1997 to propose a preamp construction article based on the HeadRoom headphone amp module. Not only did he graciously accept an article from a perfect stranger, he came down to visit me a few months later. (His son Chad teaches at the nearby Monmouth University in West Long Branch, NJ, and it turned out Chad was the faculty adviser for my niece's future husband.)

My article appeared in the June 1997 issue of *Audio Electronics*. Ed invited me to the AES convention in New York City that fall.

Thus began my long association with Ed Dell and *Audio Amateur,* leading to almost 250 more articles, reviews, test reports, and "New Chips on the Block" columns in the various *TAA* publications. Through Ed, I have become friends with many of the true experts in the audio field, for which I am very grateful.

Ed was one of the most gracious people I ever met. My wife, Kathy, always said he had a very calming voice, and he was genuinely interested in everything you had to say.

—*Chuck Hansen, frequent contributor to* Audio Amateur *publications*

CONTRIBUTORS

Vance Dickason ("Scan-Speak High-Frequency Driver," p. 34) has been working as a professional in the loudspeaker industry since 1974. He is the author of *Loudspeaker Design Cookbook*—which is now in its seventh edition and published in English, French, German, Dutch, Italian, Spanish, and Portuguese—and *The Loudspeaker Recipes*. Vance is the editor of *Voice Coil: The Periodical for the Loudspeaker Industry*, a monthly publication. Although he has been involved with publishing throughout his career, including receiving an AES Citation Award for his ongoing contribution to audio education, he still has a "day job" as an engineering consultant to a number of loudspeaker manufacturers. This currently includes Samsung, The AVC Group (Niles and Sunfire), Artison, and Emotiva.

Bruce Heran ("Podwatt Series II Stereo Integrated Valve Amplifier," p. 17) has been involved in electronics for 49 years. He built his first project—a one-transistor amplifier—when he was 13. He resides in Sierra Vista, AZ, has a BS in Biology, and studied electrical engineering for two years. In May 2011, he retired from his work as a project manager of a logistics contract with the federal government. He currently co-owns Oddwatt Audio, an electronics company that specializes in vacuum-tube audio components. He is vice president of design and support, and many of the company's products are kits and assembled audio equipment based on his personal designs.

Dr. Richard Honeycutt ("Selecting a Power Tube," p. 12) has been an audio enthusiast, musician, recording engineer, broadcast radio engineer (First Class Commercial licensee since 1969), radio announcer, electronics repairman, tube guitar amplifier designer, speaker system designer, pro-sound/video designer, and college electronics teacher. He is now a consultant in acoustics and electroacoustics. He earned a PhD in Electroacoustics from the Union Institute, and lives in Lexington, NC, with his wife, Betty Jane, near his daughter Alyson, her husband, and two of his three grandchildren.

Burkhard Kainka ("FET Amp with Valve Sound," p. 30) first contributed his article to *Elektor*. It appeared in the November 2003 issue of *Elektor* and turned out to be very popular at the time. Burkhard is one of countless people who have contributed articles about their projects to *Elektor*.

Mike Klasco ("High-Polymer Film (Part 2): Headphones, Microphones, and Other Audio Applications," p. 8) is the president of Menlo Scientific, a consulting firm for the loudspeaker industry, located in Richmond, CA. He is the organizer of the Loudspeaker University seminars for speaker engineers. Mike specializes in materials and fabrication techniques to enhance speaker performance.

Steve Tatarunis ("High-Polymer Film (Part 1): Headphones, Microphones, and Other Audio Applications," p. 8) has been active in the loudspeaker industry since the late 1970s. His areas of interest include product development and test engineering. He is currently a Support Engineer at Listen, Inc., in Boston, MA, where he provides front-line technical support to the SoundCheck test system's global user base.

Peter Touzelet ("Deconstructing the SC-OPT," p. 24) is a French aero-thermo-mechanical engineer, working as the technical director of a French engineering company. He is involved in the design and setup of large vibration systems and acoustic rooms for environmental tests. His passion for tubes began at an early age, when watching his father repair old radios for their neighbors. He likes to consider new designs proposed by experienced hobbyists and tries to use principles and mathematics to clarify design difficulties. He has been retired since 2008.

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