er area where transformer coupling can prove its worth by isolating high-frequency noise from downstream analog electronics. In addition, there are already plans to make studio and archival recordings at a doubled rate of 5.76MHz, reducing the need for noise-shaping.

This time around Sony is avoiding claims of perfection and is open about future improvements in SACD, DSD, and SBM Direct. They are encouraging high-end and mass-market manufacturers to do their own variations on DSD, and are already licensing combined DVD, DSD, and CD players to other manufacturers. When the multi-format players arrive on the market about six months from now, they will switch on the fly between between CD, 96/24 DVD, and DSD, letting the consumer and record producers decide which format they like best.

Conclusion

"Analog Is Back," and more importantly, the values of the analog era. The industry, especially the tube industry, can return to more interesting challenges of removing coloration, improving linearity, and most important, getting closer to the original sound. Bad news for tweakers and system tuners, but wonderful news for electronics and speaker manufacturers.

SPOTLIGHT

The Raven Preamp
By Lynn Olson

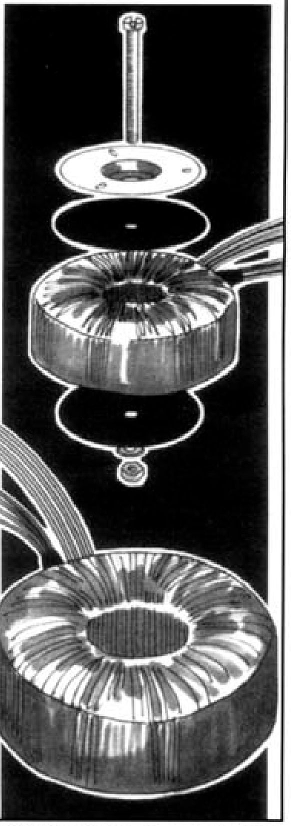
I'd like to share with readers a preamp I've been working on for the last two years. I wished to build the most linear device I could, giving special weight to low-order harmonics, while avoiding high-order harmonics, which are much more troublesome from an IM distortion point of view. I agree with Norm Crowhurst's and D.E.L. Shorter's proposals in the '50s to weigh harmonics by the square or cube of the order.

Devices

Keeping this in mind, I looked at devices first. Bipolar transistors and MOSFETs are the worst because they have lots of problems with high-order harmonics, raw distortion, and device matching for good measure. This is why no-feedback transistor circuits are very difficult to design.

AC and DC parameter shifts with temperature are a serious problem with all silicon devices, and require thermal-feedback bias circuits to prevent thermal runaway. Unfortunately, the bias circuits are always several seconds late thanks to thermal lag from the transistor die to the several-inches-away temperature sensor, so the bias is never actually correct with a dynamic signal.

Pentodes are almost as bad as transistors in pentode mode, although they make great RF amplifiers due to low Miller capacitance compared to triodes. Device matching is not a problem, at least compared to transistors. Pentodes in quasi-triode (the misnamed ultralinear) and triode mode are about three times more linear, which is a big improvement,



but still not as good as the best possible.

The most linear devices are true triodes, which are about three times as linear as triode-connected pentodes. The most linear triodes of all are the ancient direct-heated triodes, at least for power devices. Oddly, indirect-heated power triodes are not as linear as a DHT equivalent. For driver tubes, though, there is no measured advantage to DHT, and a lot of problems with DC heating to contend with (DC on DHT doesn't sound good unless done very carefully).

I selected the 5687, 7044, and 7119 family of early-'60s computer tubes. The 6SN7 is just as good, maybe even a bit better, but the R_p is three times higher, and thus really cuts into the bandwidth you get with a transformer. (One or both sides of the coupling transformer must be at a low impedance if you desire good bandwidth.)

Transformers

Why transformer coupling with all of its perceived limitations? Transformer coupling has about 3–5 times lower distortion than RC-coupling (as a result of its flat load-line and constant-current operation), with the only real penalty being a requirement for a low R_p value from the tubes and accepting more distortion in the sub-50Hz region (but much lower everywhere else). The minor penalty of a bit more LF distortion is an acceptable tradeoff in return for upper harmonics declining several-fold (since the highly nonlinear low-current region is avoided).

Modern transformers combined with high-g_m, low-Z tubes allow wide bandwidths, from 14Hz out to 85 and 100kHz. With SE and its requirement for large DC currents (thus large cores, thus more stray Cs), the bandwidth falls to 30–40kHz at best, which is a somewhat less acceptable tradeoff. One thing that parafeed restores is wide bandwidth, since the DC-supplying chokes need not be wideband, and there is no DC through the audio transformers, so they can be smaller and more wideband.

Circuit Topology

As for circuit topology, SE (single-ended) has the reputation of being the transparency and "directness" champ, while PP (push-pull) has the reputation of power and bandwidth. There is merit to both points of view, but the important question is why they sound that way. In particular, PP is usually achieved with an active phase-splitter, which does not really do a stable job of phase inversion. The output impedances are dissimilar even with a long-tail pair, and grossly so with the more typical split-load inverter.

Worse, the Miller capacitance is dissimilar as well, so the harmonic structure changes with frequency as even harmonics drift in and out of cancellation. Change the line voltage or operating current, and the splitter changes as well, not to mention the splitter introducing its own distortion, which is not common-mode cancelled by the following circuitry.

I wished to explore what the textbook best-case would be: true Class-A fully matched pairs with identical grid drives and identical loads. Only transformers can accomplish this, and even then, special winding techniques must be used to preserve equal capacitance between the paired windings—one of the most important differences between cheap PP transformers and really good ones (*Fig. 1*).

Power Supply

With the extremely simple forward path done, what about noise, or perhaps more important, power-supply colorations? The choice of power-supply cap can make a big and unwanted difference to the sound of any tube product. In effect, the cap both shunts power-supply noise and acts as a low-impedance reference point for the audio signal path. It's being asked to do two things, and does neither well.

The parallel-feed circuits being explored by Dan Schmalle (*VALVE* magazine and Electronic Tonalities) have a powerful advantage in inductively isolating the power supply from the signal path. I took parallel-feed a step further by resistively isolating the AF chokes from the signal path. One of the sources of coloration in AF chokes (which are not at all the same as power-supply chokes) is stray capacitance from the windings to the case (which is grounded). Although small, this capacitance is not particularly high quality, and the resistor provides an extra bit of isolation.

Going further into the power supply, solid-state diodes can make a lot of hash, which is then both radiated into the air and sent outward on the AC and DC lines to which the diodes are connected. The diodes snap-off and shock-excite the LC circuit of the stray C of the PS transformer and the series L of the main smoothing caps. The frequency of this

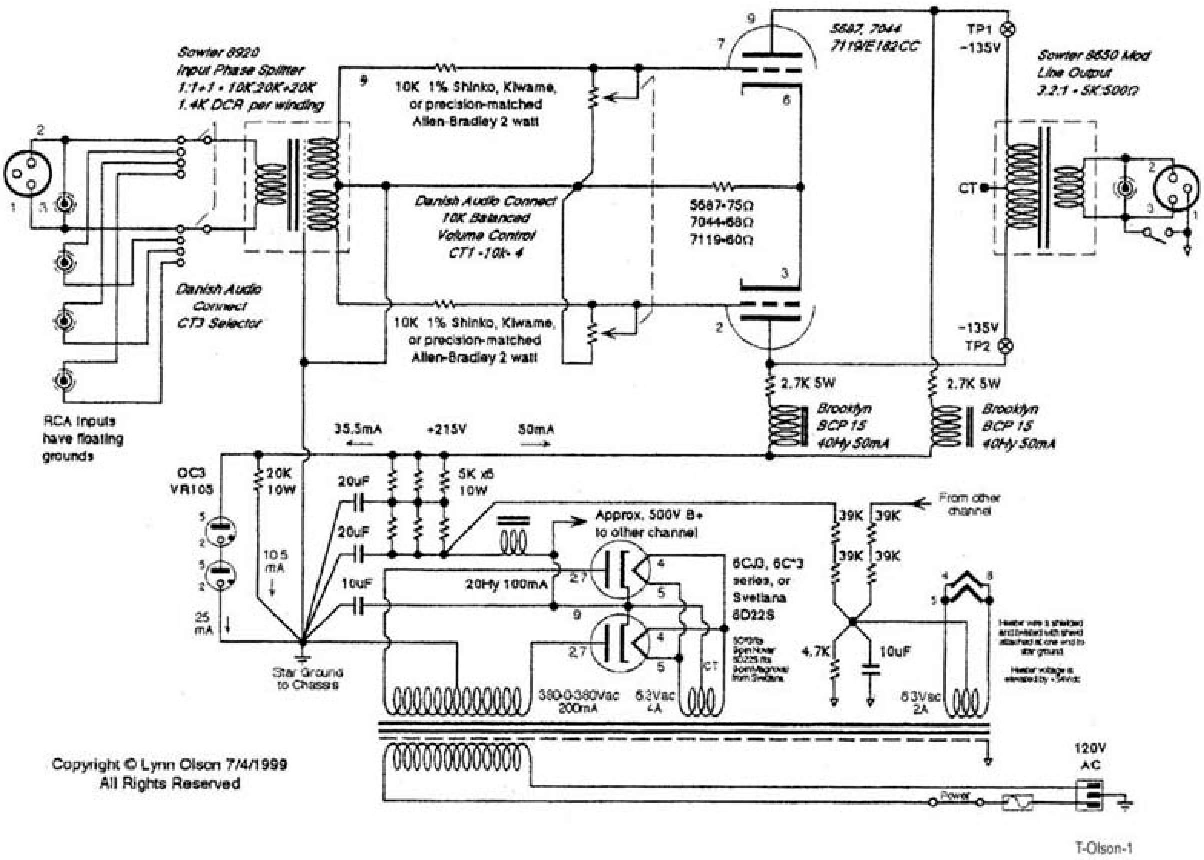


FIGURE 1: Schematic of the Raven preamp.

resonance is typically somewhere between 5–25kHz. Yes, you can build a resonance trap, but why bother?

The circuit will need to be precisely retuned every time you change vendors for the power transformer and power-supply capacitor. Better to avoid silicon diodes entirely, and go with low-drop, high-current TV damper diodes, which also have smooth curves in the on-off regions. Fortunately, NOS stocks of the 6C*3 family are abundant, as well as the excellent new 6D22S (and matching sockets) from Svetlana.

AC/DC

As for AC versus DC heating of the low-level triodes, much of the hum can be sidestepped by elevating the heater and presenting a low-impedance AC path from heater to ground in the event of some heater-cathode leakage. Center-tapping the heater winding and twisting the heater cable makes the AC supply a 3.15V differential signal instead of 6.3V single-ended, which reduces emission into the chassis and from the heater itself into the cathode.

The differential AC can be pretty quiet, as DHTs lit by 5V AC will attest, with almost none of the 5V appearing on the virtual cathode, despite the fact the real filament has several volts of AC on each end! It works even better with physical cathodes, since the entire cathode is at the same electrical potential, and responds to the AC fields from the heater as a whole. Set the net value of the heater AC field to zero (common-mode rejection), and AC heating can be very quiet indeed, especially with a PS transformer with a shielded primary.

How will the Raven preamp sound with 96/24 and SACD? Good question! I'm looking forward to seeing how low-distortion triodes combine with low-distortion, analog-sounding recordings.

Further Reading

Positive Feedback Magazine
David Robinson, Editor
9388 S.E. Hunters Bluff Ave., Portland, OR, 97266
(503) 771-6300, FAX (503) 771-6400
E-Mail davidr@transport.com
Website http://www.positive-feedback.com

VALVE/Electronic Tonalities
Dan Schmalle, a.k.a. Doc Bottlehead
(360) 697-1936
E-Mail bottlehead@bottlehead.com
Website http://www.bottlehead.com

BUILD A LOW-DISTORTION COMPRESSOR

By Rickard Berglund

Many circuit topologies are possible for use in tube compressors. Although most of these designs produce a high distortion level, the balanced topology presented here produces very low distortion.

As shown in *Fig. 1*, the input signal is fed to a line transformer. The transformer's secondary winding must have a center tap. The secondary impedance can be anywhere in the range of 600Ω–10kΩ. The input signal is fed to the right part of tubes V1 and V2. The signal is also fed to the left parts of these tubes, although in opposite phase and at only one-tenth of the amplitude. The grid of the left part is normally held at –2.5V when no compression occurs. When compression occurs, the grid potential becomes positive, while the current in the left section increases and the current in the right portion decreases. The end result is a reduced output amplitude.

The signal from V1 and V2 is then fed to the long-tailed pair, V3. The signals added to the long-tailed pair cancel the second-order harmonic, the most dominant source of distortion from tubes V1 and V2. The output from V3 is fed to cathode follower V4A.

to page 37

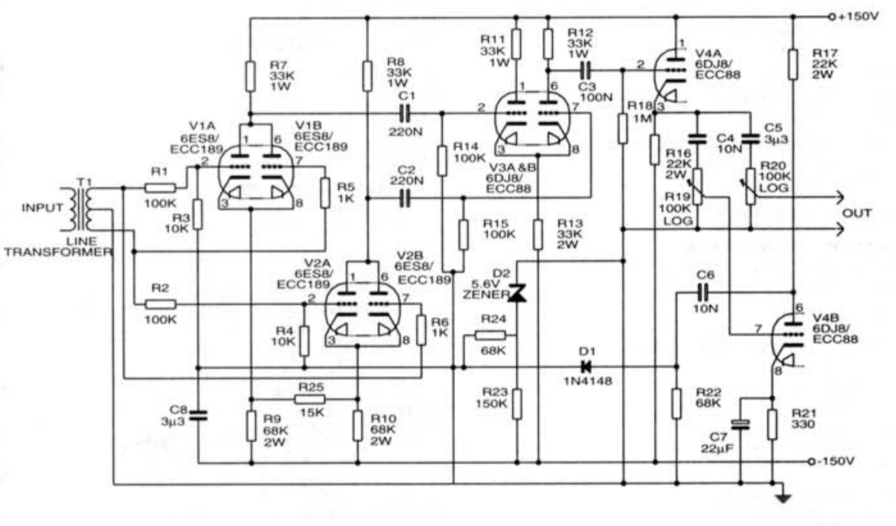


FIGURE 1: Low-distortion compressor circuit topology.

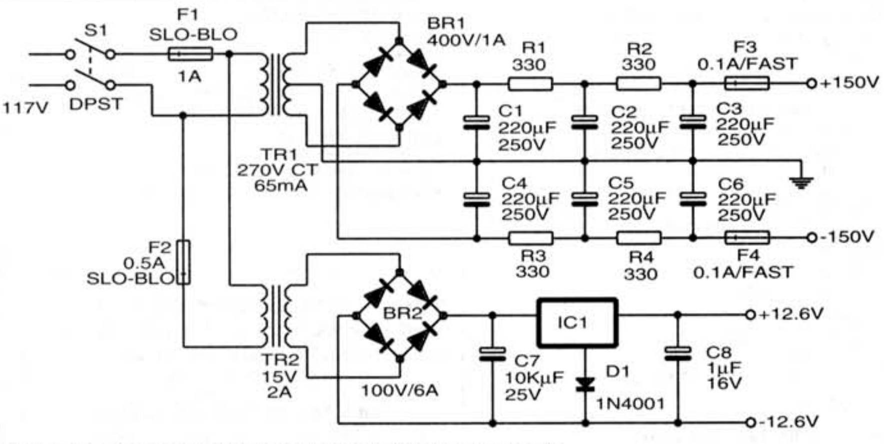


FIGURE 2: Power-supply schematic for a stereo compressor.

TABLE 1

PARTS LIST

COMPRESSOR RESISTORS	
R1, R2	100k
R3, R4	10k
R5, R6	1k
R7, R8, R11, R12	33k 1W
R9, R10	68k 2W
R13	33k 2W
R14, R15	100k
R16, R17	22k 2W
R18	1M
R19	100k log. potentiometer
R20	10k lin. potentiometer
R21	330Ω
R22, R24	68k
R23	150k
R25	15k
CAPACITORS	
C1, C2	0.22μF
C3	0.1μF
C4, C6	10nF
C5	3.3μF
C7	22μF
C8	0.33μF
MISCELLANEOUS	
BR1	1N4148
BR2	5.6V zener diode
V1, V2	6ES8/ECC189
V3, V4	6DJ8/ECC88
TR1	Line transformer
POWER SUPPLY	
R1–R4	330Ω 2W resistors
F1	1A slow-blow fuse
F2	0.5A slow-blow fuse
F3, F4	0.1A fast fuse
BR1	400V 1A bridge rectifier
BR2	100V 6A bridge rectifier
D1	1N4001
C1–C6	220μF 250V cap.
C7	10,000μF 25V cap.
C8	1μF 16V cap.
TR1	270V 65mA CT transformer
TR2	15V 2A transformer
IC1	12V 2A regulator

Tube Compressor

Continued from page 32

Potentiometer R19 sets the compression level, while the output level is determined by R20. The signal from R19, amplified by V4B and rectified by diode BR1, charges capacitor C8 during compression. C8 then discharges through the resistors R1, R2, and R24. The time constant for charging and discharging is approximately 10mS.

BALANCED OUTPUT OPTION

If you prefer to have balanced outputs, add another cathode follower from the left anode of tube V3. The input signal to the compressor should be in the 0.1V–1V range. If you'd rather not use a line transformer at the input, you can use op amps to balance the signal instead. The power supply, presented in *Fig. 2*, shows the filaments connected two-and-two in series to the 12.6 volt. ♪

from page 1

Society. Over time, the tail started wagging the dog, and at one point, *PF* probably had more writers than the OTS had members! After designing the Ariel transmission-line speaker for magazine readers, I was drawn back into electronics again, and began to collaborate with my Tek friend Matt Kamna on a series of articles for *Sound Practices* and *Glass Audio*. There are more articles in the pipeline planned for *Glass Audio* and *V&T News*.

Today's Transformers

The lead article for this issue is the result of research on the subject of linearizing driver stages through the use of transformer coupling, which is well-suited to nonfeedback vacuum-tube amplifier design. The traditional objections to transformers, of course, are limited bandwidth and high distortion.

With modern transformers from Magnequest, Electra-Print, Jensen, Tango, Tamura/Sun Audio, SJS Electroacoustics, Sowter, and many others, these objections have been largely eliminated. High-frequency bandwidths of 70–120kHz are not unknown, and distortion is now confined to subsonic frequencies below 20Hz. The recent popularity of the single-ended triode amplifier is due, in part, to the greatly improved performance of output transformers that can accept 60–100mA of DC current and still maintain respectable bandwidth and power-handling. In the "old days" of the original Western Electric 91A amplifier, modern performance figures of 20Hz–40kHz would have seemed astounding. These days these values signify only a "pretty-good" SE output transformer.

Even ancient circuits using interstage and input transformers are being taken seriously again due to improvements in these types of transformers. With classic Williamson, Acrosound, Marantz, and guitar-amp circuits, of course, interstage transformers are still out of the question, due to the difficulty of maintaining phase margin with 12–20dB of overall negative feedback. The Lundahl LL1621 discussed in the accompanying article is an interesting solution to the problem of out-of-band phase margin, and could successfully replace RC-coupling in a "classic" circuit. This would provide a significant reduction in distortion due to the more relaxed working of the driver stage, as well as improved bias stability and clipping performance for the output tube.

You'll find *V&T News* offers an interesting mix of news articles, technical analysis, reviews of test equipment and software, and pointers to Web sites of interest on the Internet. Since the community of vacuum-tube professionals is so diverse, and spread all over the world, you can help by keeping us informed of any new developments of interest to the vacuum-tube community (ultra-fi, high-end, vintage, and guitar amps).—**LO**

SPOTLIGHT

Lundahl & Southeastern Transformers

By Lynn Olson

In the course of developing a push-pull zero-feedback triode amplifier over the last two years, I discovered Lundahl Transformers of Sweden. Although Lundahl may be familiar to European readers, I expect this line of microphone, input, interstage, and output transformers will be of considerable interest to North American and Asian readers—for several reasons:

A. Overall performance and bandwidth are comparable to high-end Japanese transformers (I have measured −1dB

How to Reach Us

Editor (USA):
Lynn Olson, phone/FAX (503) 642-7168
E-Mail lynno@teleport.com
http://www.teleport.com/~lynno/Ariel.htm

Italian reporter:
Luciano Macrì, phone/FAX (+39) 55-43-61-624

German reporter:
Andreas Schubert, phone/FAX (+49) 30-687-4560

Danish reporter:
Hans Mortenson, (+45) 53-77-75-77
FAX (+45) 53-77-75-60
E-Mail m1124@skole-kom.uni-c.d

Swedish reporter:
Rickard Berglund, FAX (+46) 413-21502

Finnish reporter:
Jukka Tolonen, (+358) 0-257 942, FAX (+358) 0-488-814
E-Mail tolonen@megabaud.fi

Canadian reporter:
David O'Rourke, (416) 694-4642

Australian reporter:
Mark Kelly, phone/FAX (+61) 3-5726-1615

bandwidths from 70–100kHz), but costing two to five times less. No, they don't come in elegant potted cases, so under-chassis mounting is pretty much required. The flat profile (halfway between a toroid and an EI core) makes the under-chassis mounting simpler than it might appear at first glance.

B. All transformers employ an unusual single C-core construction combined with matched dual bobbins. The identical bobbins on each side of the C-core automatically provide exact pair-matching for push-pull applications, which is very difficult and costly for single bobbin construction. With single bobbins (as in EI and double C-cores), exact pair-matching over the entire frequency range requires complex interleaving and successively finer gradations of wire gauges.

C. Loss of pair-match at high frequencies is part of the "push-pull sound" that has been criticized by designers of single-ended amplifiers. Precision matching of the entire push-pull circuit (in and well beyond the audible range) assures a consistent second- and third-harmonic structure over the audio spectrum.

D. The product line is extensive, with microphone, line input, line output, interstage, and output transformers (*Photo 1*). Within this line are many interesting models, with a selection of mu-metal, SiFe, and amorphous core materials, as well as many different winding ratios for different applications.

E. All primaries and secondaries are independently brought out to the terminal block—instead of the inaccessible center-tap design inside the bobbin—to allow the amplifier designer a choice of a wide variety of connection possibilities, as well as more unusual applications such as tertiary-winding feedback (no more feedback-compensation circuits for different impedance speakers). This arrangement requires a small plugboard for accommodating 4, 8, and 16Ω speakers when using the Lundahl output transformers.

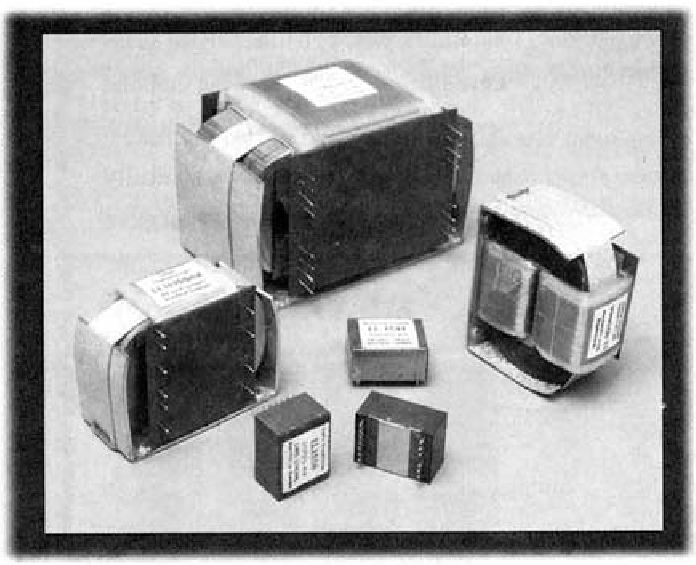


PHOTO 1: A sampling of Lundahl Transformer's product line.

F. Lundahl is a family-owned business that has been supplying the European professional-sound market for 30 years. While they don't do custom designs as far as I can tell, they are coming out with new designs that cater to both the existing push-pull market and the emerging single-ended market. For example, the output transformers are available in push-pull, 40mA, 60mA, and 80mA versions, and the interstage transformers are available in push-pull, 5mA, and 20mA versions.

Output

The output transformers are rated for 62–250W push-pull, or 13–50W single-ended (all have the same size core, with different size gaps and winding ratios). The LL1627, LL1623, and LL1620 models are available with permissible DC offsets of 8–16mA (PP application), and values from 40mA–185mA for single-ended applications (depending on primary impedance and gap size).

For example, the LL1620 output transformer is available as the LL1620/PP, LL1620/40mA, LL1620/60mA, and the LL1620/80mA, depending on gap size. The other transformers have similar designations.

I am using the LL1620/PP output transformer for my own push-pull design, since it offers a 125W power rating, a 6.6kΩ primary impedance, and a selection of 4, 8, and 16Ω connections on the secondary. With matched VV30Bs (effective plate-to-plate Rp = 1.5kΩ), the LL1620 has a −1dB high-frequency (HF) bandwidth in excess of 85kHz with excellent square-wave response. The circuit produces 16W at less than 0.25% distortion, which is pretty good considering the absence of local or overall feedback (cathodes are bypassed).

The output transformers cost 1079 Swedish kronor (SEK) for single quantities, 809 for ten or more, and 539 for 50 or more. (The current exchange rate is 7.90EK = US$1.) US pricing for the LL1620, LL1623, and LL1627 models are $136.55 for each unit, $102.41 for ten or more, and $68.27 for a quantity of 50 and greater. Additional discounts are available for larger quantities.

Interstage

The interstage transformers are all 1:1, although other connections are possible. I am using the LL1635, which is available in LL1635-PP, LL1635-5mA, and LL1635-20mA versions. With plate-to-plate impedances of 5kΩ, the LL1635 has a −1dB HF bandwidth around 80kHz. Lundahl provides recommendations for RC-networks across the secondary to further improve square-wave performance, although I have not yet tried this.

The LL1621 "non-inverting" transformer is a 1:1 interstage that is designed to use a 0.1μF capacitor bypass between primary and secondary. This provides a very extended HF bandwidth of 600kHz, allowing the use of an interstage transformer with feedback amplifiers, and also offering low-distortion benefits of transformer coupling. (Measurements conducted by Matt Kamna of Tektronix indicate that IT-transformer coupling has half the distortion and twice the linear swing of RC-coupled drive stages, due to the almost horizontal load-line seen by the driver tubes.) The LL1621 is available in push-pull (LL1621-PP) or single-ended (LL1621/6mA) versions.

For push-pull amplifiers, there is the additional advantage of exactly symmetrical drive voltage for the power tube grids, regardless of line voltage variations, heater power, cathode emission, or other variables. This sidesteps the problems of phase inverters, since even if the preceding stages use a conventional split-load inverter or long-tail pair, it is all balanced out in the interstage transformer before the signal reaches the output stage grids. The requirements for driver-tube matching and precise circuit setup in the driver and input stages are greatly simplified.

For interstage transformers, the prices are as follows. The LL1635 transformers are priced at $63.72 (or 503 SEK) each, $47.79 (377 SEK) for quantities of ten or more, and $31.86 (252 SEK) for 50 and above. The LL1621, however, costs $59.74 (472 SEK) for single units, $44.80 (354 SEK) for ten and above, and $29.87 (236 SEK) for quantities of 50 or more.

Input

I am also using the Lundahl input transformers, which provide benefits from a high common-mode rejection ratio (CMRR), and also isolating ground-borne noise from the power amplifier circuit grounds. The disadvantage of any input transformer (such as Lundahl, Jensen, Tango, Tamura, and others) is the requirement for a low source impedance from the preamplifier, preferably well under 600Ω. If this is not met, the 60–100kHz bandwidth drops to a much lower figure. In particular, you must avoid passive volume controls, with their very high (and variable) source impedances, as well as preamps with plate circuits RC-coupled to the output. Although these are rare (remakes of the Dyna PAS-3x come to mind), results will not be satisfactory with any type of input transformer.

Marketing Issues

Although an input transformer provides many benefits—precise balanced-to-unbalanced conversion, very high CMRR noise rejection (even with unbalanced RCA inputs), and isolation of ground noise and hash (from digital, television, and RF devices) from the rest of the amplifier—each designer needs to weigh the marketing disadvantages of restricting the choices of the dealer and the consumer. Passive "pre-amps" are still popular with many audiophiles, both to save money and to avoid the sonic penalties of indifferent preamp design. Very few audiophiles are aware of the drawbacks of driving 300pF of cable capacitance with a source impedance of 10–50kΩ.

Rather than go through the trouble of re-educating the dealer and the customer on the importance of source impedance, selecting an input transformer for a power amplifier may result in an additional commitment to design a matching low-output-impedance preamp. This avoids the education problem, since the preamp and power amp can be recommended as complementary units. If the preamp also uses an output transformer (as was conventional studio practice in the "old days"), the buyer can then choose between fully balanced XLR or unbalanced RCA interconnects based on personal preference.

The line-driver transformer in the output section of the preamp also removes any possibility of DC offsets or turn-on/turn-off thumps damaging the buyer's power amplifier—no complex DC servo circuit is required, and there are no large output capacitors to charge or discharge into the delicate input transistor or input-tube grid of the consumer's power amplifier.

(Although the amp/preamp can always be recommended as a combination, few audiophiles can resist a mix-and-match session with their friends. With good reason, makers of transistor amplifiers do not look kindly on RC-coupled vacuum-tube preamps, which can all too easily damage the entire input section of the power amplifier if something goes wrong in the preamp. Transistor preamps may also fail in the DC servo, which can damage a DC-coupled power amplifier just as quickly and destructively.

I was present when just such a scenario happened to an editor of a well-known audio magazine, taking out not only the DC-coupled amp but the woofers as well. A ten-cent part failure in the preamp ended up damaging $15,000 worth of power amp and speakers. A bright flash from inside the speaker, followed by a small wisp of smoke from the amplifier, told the tale.

With transformer isolation, DC offsets and near-DC thumps are never a problem. The transformer core saturates and the primary goes open in the worst-case scenario.)

Lundahl makes a number of different input transformers with 1:1, 1:2, and 1:4 ratios. I am using the LL1544, but will also be experimenting with the LL1554 and the LL1550. The input transformers are available with either mu-metal or amorphous cores. The company claims that mu-metal has lower measured distortion, but amorphous cores have better subjective qualities.

Prices for the 1544 are: 360 Swedish kronor for single quantities, 270 for 10 or more, and 180 for 50 or more ($45.52, $34.14, and $22.79, respectively). The prices for the other models of input transformers are within 10–20% of these figures.

I recommend a visit to the Lundahl Website to sort out all the different models, especially the input transformers. The site also provides a bit of historical background as well as the general philosophy of the company. If you have the Acrobat PDF reader for your browser, you can download the spec sheets, print them out, and read them at your leisure. The price sheets are not yet available on the website; send an E-mail or FAX to Lundahl for the current price list. Please note that the Lundahl staff is unable to assist consumers with design questions on an individual basis. AB Lars Lundahl, Tibeliusgatan 7, S-761 50 Norrtalje, Sweden, (+46) 176-139-30, FAX (+46) 176-139-35, E-Mail adm@lundahl.se, Website http://www.lundahl.se.

Southeastern Transformers

For the custom-designed power transformer and choke of my amplifier, I am using the products of Southeastern Transformers in Florida. I first heard about them from a fellow triode-amp designer, Reid Welch, who was very satisfied with the power trans, choke, and custom interstage that Southeastern designed for him. The mention of an interstage caught my attention, since ITs are notoriously difficult to design for low distortion and good bandwidth, while still working successfully with medium-value plate impedances from the driver tube. I later learned that Southeastern has a consultant who was one of the long-time staff engineers at UTC; it's nice to know that the arcane knowledge of how to build good audio transformers has not been lost after all.

I was also pleased to work with Southeastern because they could handle my requirements for 3% regulation and separate electrostatic shields (ES) for the primary and the filament secondary, turning the job around in two weeks. The transformers were quiet (no buzzing laminations) and had low magnetic-field emission. Southeastern is also equipped to ramp up for a production run.

Designing power transformers for filament-powered triodes is a bit trickier than for more conventional pentodes, since now you have a number of floating supplies, and at different voltages. The use of an ES for the primary may seem obvious (very simple and cost-effective rejection of line noise), but what was the reason for the shield on the filament supply?

Noise Sources

Matt Kamna and I analyzed the sources of noise in filament-heated tubes and came up with some surprising results:

1. The major problem is not 50/60Hz hum; rather, it is the harmonics at 100/120, 150/180, 250/300Hz, and so on. This is due to the Fletcher-Munson effect, in which the ear is not very sensitive to low-frequency energy compared to the midband. Thus relatively high hum figures are fairly harmless, but the harmonics and buzz components are not.

2. A significant source of these upper-frequency components actually comes from capacitive coupling from the high-voltage (HV) secondary. It may seem unlikely that a mere 30–100pF of inter-winding capacitance could be any trouble, but remember, the HV secondary is operating around 400–500V, at least 100X more voltage than the filament circuit. In addition, the HV secondary is connected to a rectifier, which is an abundant source of noise (one of the reasons for the "sound" of tube vs. solid-state rectifiers is the spectrum of this noise).

3. The noise capacitively coupled into the filament circuit is not removed by the use of DC regulation on the filaments! The direct-heated triode is almost completely insensitive to differential-mode signals; it can reject a full 5V of 60Hz with no trouble. Unfortunately, differential-mode signals are the only ones improved by regulation; common-mode noise (in which the two terminals move up and down at the same time) is not affected at all! The triode responds strongly to common-mode signals, since the tube amplifies the voltage change between the center of the virtual cathode and the grid. The tube neither knows nor cares whether it is the grid or virtual cathode that does the moving.

Solution

The only way to really reduce the induced common-mode noise is electrostatically shield the filament winding from all other noise sources. Fortunately, this is not difficult for the transformer builder to do; all you have to do is ask. Does it clean up the sound of direct-heated triode amps? Yes, by both spectrum analysis and listening. Even with straight unregulated AC on the heaters, all that comes out of the amp is a trace of 60Hz hum, but no buzz or hash is audible.

Readers who design pentode amplifiers may find the foregoing hassles rather comical, but this issue affects you, too. Not all modern tubes have good heater-cathode isolation; the ones that don't are considered "noisy" or "hum-prone." Rather than go through a labor-intensive process to sort through these (and ask the customer to do the same afterward), why not specify an ES for the heater windings on the power transformer? That way you can use tubes that would otherwise be too noisy. Also, the good ones will be extra quiet due to the cleaner 50/60Hz sine wave for the heater power.

Both Lundahl and Southeastern Transformers are willing to step out of the tried-and-true, and for vacuum-tube amplifiers, that can mean the difference between a good amplifier and great one.

SOURCES

Lundahl Transformers
Tibeliusgatan 7, S-761 50 Norrtalje, Sweden
(+46) 176-139-30, FAX (+46) 176-139-35
E-Mail adm@lundahl.se,
Website http://www.lundahl.se.

Southeastern Transformers
Ed Edlund, President
2114 SW 60th Way, Miramar, FL 33023
(954) 963-2890, FAX (954) 963-2331

INDUSTRY NEWS AND DEVELOPMENTS

Oil-Filled Capacitors

In the course of designing many high-end speakers, I've come to know all too well the subjective colorations that capacitors can impart to the overall sound. It doesn't really matter whether the capacitor is the speaker crossover, a coupling cap between stages, a cathode bypass, or in the power supply; they're all audible, just different in degree.

The invaluable work done by Walt Jung in the early '80s pointed the way to avoiding caps with poor DA and DF properties, which are easily measured with a lab-grade capacitor tester (from Fluke and others), and so, it is now common practice to seek out high-quality parts for the signal path.

DA and DF measurements, though, do not tell the whole story. Those of you who have built dummy loads that simulate loudspeakers have already discovered that capacitors "sing" at high power levels. My Tek friend Matt Kamna has also discovered that when caps are polarized (as in RC-coupling, bypass, or power supply use), they act as condenser microphones with a very rough and resonant response curve. (Yes, we tested this with a mechanical driver, a spectrum analyzer, and a tracking generator.)

So the mechanical properties of capacitors can be as important as the better-known DA and DF characteristics. Although I don't advocate dunking your favorite polypropylene cap in an oil bath, it's time the industry took a second look at oil-filled capacitors.