Back

Topology, Measurements, and Screen Taps

By Dennis Colin and John Stewart

PHOTO 1: "Mad Katy" 125W per channel stereo amp.

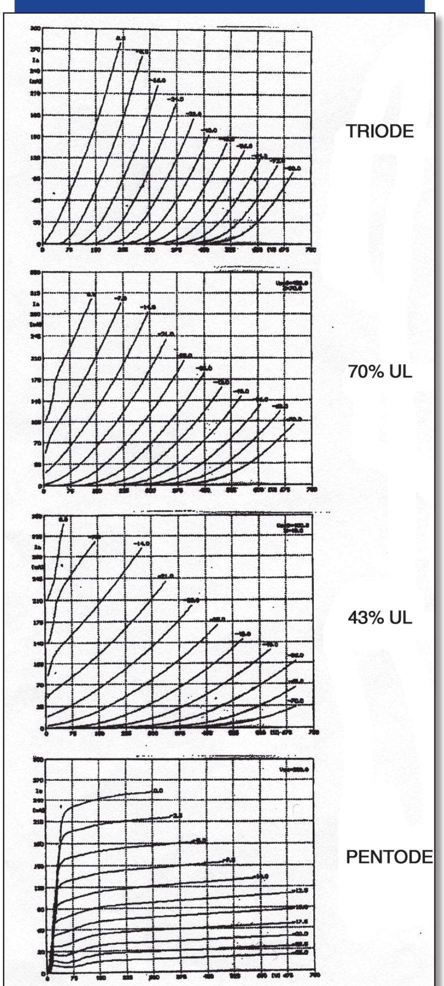
John Stewart's article, "Norman Crowhurst's Twin Coupled Amp . . . And Beyond" (*aX* 8/04), has helped confirm the following assertion: No particular amplifier topology with continuous signal transfer (e.g., excluding class B, C, and so on) is necessarily bound to a certain limit on achievable sonic fidelity. What's important, of course, is the output signal integrity, regardless of the pathway.

While a simple topology can occasionally "arrive there" by chance, more complex ones are very likely to require intensive attention to all the sonically relevant engineering principles, notable examples of which are quoted from Norman Crowhurst on page 12 of the article.

Sometimes the goal is not intrinsic fidelity, but rather a specific amplifier sound (e.g., "warm," "romantic," "tubey," and so on). Euphonic colorations (such as added second harmonic or low DF response dependence on speaker impedance) can add warmth or spaciousness, which can sometimes compensate for the lack thereof in many recordings due to, for example, excessively close miking, narrowly focused speakers, and 16/44 CD resolution limits. (Not to mention the inability of even five channels to reproduce the three-dimensionality of a million ft^3 concert hall!)

Returning to the goal of intrinsic fidelity, I'd like to address the "partial triode" mode Mr. Stewart referred to: ultralinear (UL) with high screen-tapping ratios. **Figure 1** shows (from Audiomatica) KT88 curves for pentode (0% tap), 43% UL, 70% UL, and triode (100% tap). Notice how triode-like the 70% UL curves are; the most significant difference is that the tube can pull a lower plate-cathode voltage drop during high conduction, resulting in greater power output.

FIGURE 1: KT88 characteristics.



I recently completed "Mad Katy," a 125W per channel stereo amp (**Photo 1**). Each channel uses four KT88s (from JJ) in forward-linearized class AB with 67% screen tapping. This produces 130W at 1% THD, which is more than twice the 60W of triode mode, but only 1dB less than the 165W obtained with 33% UL operation, all with a +500V supply.

Provided that the transformer output top impedance selected (2, 4, or 8Ω) is no greater than the lowest speaker impedance magnitude across the band, the sound was possibly indistinguishable from that with a 3W single-ended EL84 unit (up to 3W peaks, of course) in a 0.05dB level-matched A/B comparison. By itself, the amp showed no audible degradation up to full power. The sound is very natural and solid with well-recorded SACDs, and with live-miked voices and bells, using the Panasonic WM-60AY capsule (that was used in Mitey Mike).

Some waveform responses are shown on pages 67-68 of *aX* 4/04. The high screen-tap "partial triode" mode appears to work very well. I obtained the 67% tapping by unsoldering the twisted-pair primary leads of the Plitron PAT-4142-00 transformer, revealing isolated screen windings (originally 33% tapping), then rewiring.

Incidentally, I recommend the IRFBE30 power FET (800V, 4.1A, $2.24 from Digi-Key). One has been providing +500V at up to 1.5A in my amp for about a year (including abusive testing such as shorting the outputs during sustained overdrive). But I'm not using the FET as a regulator (I blew one trying), rather as a simple ripple filter and standby switch.

LACK OF CORRELATION BETWEEN SOUND AND MEASUREMENTS

I propose the following (partial) list of reasons:

1. We're not measuring enough of the relevant things; perhaps a more music-like complex signal such as a 10-tone wideband IM test would be more revealing.

2. Testing should be into a speaker-type reactive load (*Stereophile* uses a standardized LCR load, but only to evaluate response variations due to non-infinite DF).

3. We're not measuring non-waveform-distorting "long-term nonlinearities," such as compression or other gain modulations, from supply sag and/or bias shifts with signal amplitude.

4. We might not be interpreting measurements with regard to "psychoacoustic mapping." For example, response variations affect not only tonality, but also imaging, detail, and spaciousness; added harmonics may add "detail," and so on.

5. We might not *prefer* the highest intrinsic fidelity (reasons cited near the beginning of this letter).

6. Sonic evaluations could be flawed by expected bias and/or non-rigorous comparisons.

7. Human hearing, with its tremendous resolution, could be perceiving subtle distortions too small to measure.

VARIABILITY INTRODUCED BY LOW DAMPING FACTOR

Some effects are:

1. Bass peak around speaker's resonant impedance rise.

2. Response variations tracking speaker Z curve across the band.

3. Sensitivity to speaker pair Z mismatch: this adds stereo amplitude and phase imbalances, which can produce a sensation of spaciousness (these imbalances are the principles of synthetic "surround" processors).

I find it strange that some worry about 0.2dB errors in an RIAA curve, while ignoring response errors from a low DF (which can approach 6dB, as **Table 1** shows).

TABLE 1 Response increase, dB (valid for resistive loads only)

R_{SPKR}/R_{NOM}	Damping Factor: 1	2	5	10	20
2	2.50	1.58	0.76	0.40	0.21
5	4.44	2.69	1.24	0.66	0.34
10	5.19	3.10	1.41	0.74	0.38
Open load	6.02	3.52	1.58	0.83	0.42

One way to achieve a high DF in tube amps, without global NFB, is to use a small amount of local positive current FB (sensed by low-value output cathode resistors). Essentially infinite DF, and even a small negative output resistance, can be achieved without compromising stability.

I thank Mr. Stewart for his excellent article.

Dennis Colin
Gilmanton I.W., N.H.

John Stewart responds:

Thank you for your letter in response to my article. In authoring a series of articles covering vacuum tube amplifiers, my primary objectives have always been good performance at reasonable cost and the assurance that the critical parts would still be available for some time. Many amplifiers in the literature today fill only one or neither of those criteria.

My version of Crowhurst's amplifier is not meant to be high-class but does offer very good value to the home constructor who has limited resources, just as Crowhurst had intended in his original series of articles covering his Twin Coupled Amplifier design.

What we perceive when listening to this or that amplifier in my opinion is that the average person will be unable to tell the difference as long as the amplifier is able to properly drive its loudspeaker. However, I believe there are some who can probably hear differences between various amplifiers. For example, those who service a variety of amps or are oth-

PHOTO 2: 3W amp RHS1.

erwise in contact with different systems on a day-to-day basis would have the opportunity to compare. Not many of us are in that position. I am not a critical listener for the most part; I depend very much on my test equipment to tell me whether I've succeeded.

Having said that, there are important applications in which the user intentionally sets up the equipment to distort in a particular way. A good example is the amplifier used by a rock guitarist, but that is a different path than I have pursued. In my designs I would prefer you did not "hear" the amplifier at all, but the program material as much as possible.

Provided that the amplifier used is of good quality, I think that the loudspeaker in its box and the listening environment have a much larger influence when it comes to enjoyment of the program material. As Mr. Colin's letter mentioned, a 3W amplifier may sound as good as another of much higher power in a good setting. By coincidence, I have a 3W fully integrated amp of my own design that I built in 1968. It uses a 6AU6/6AQ5 feedback pair in its SE output circuit and does sound good, even in my workshop (**Photo 2**).

For many power pentodes and beam tubes it is possible to plot a first approximation of the zero bias curve for UL operation from the plate family where the screen voltage has been used as the variable. That allows a quick estimation of the audio power you might expect from a particular hookup. It also gives a good indication of what the resulting amplifier's source impedance will be.

On the plate family of a 6L6GC I've plotted the zero bias curve for three settings of UL (**Fig. 2**), one of them being triode connected (100% UL). From the slope of each curve is an estimate of the plate resistance at zero bias. The operating plate resistances will in each case be about two times these values for Class A operation while Class AB operation is about three times.

A ten-tone wideband test would be difficult to implement, so perhaps we could take a lesson from the RF industry. For example, any CTV system is expected to handle on a regular basis a far more complicated mix of signals while minimizing interference. A useful measurement technique uses three RF generators, all phase-locked to each other. The information gathered is then used to optimize the system.

Electrical network theory tells us that the current at any point in a series circuit is the same as at any other point. In the output circuit where an amplifier is driving a loudspeaker, there are at least three resistances and three reactances in series. The resistances are the loudspeaker, the speaker leads, and the output resistance of the amplifier, which is related to the damping factor (DF). There is a similar group of reactances. In general (but not always) when measuring the output system you ignore the speaker leads since their contribution to the result will be small.

The amplifier DF has considerable effect on the resulting plot of speaker terminal voltage versus frequency, as Mr. Colin shows in his table. However, due to the resistance of the speaker coil itself, DFs beyond a certain point make little difference. That is because the resistance of the speaker coil is always in series with the output system, no matter what you do. Back EMF from the loudspeaker coil must overcome the voice-coil resistance in order to have any effect on the amplifier output. You really need to measure the acoustic response of the system with a set of calibrated microphones.

Many years ago I built a small amplifier for a friend using a push-pull set of 6AQ5s. I inserted a short piece of resistance wire into one of the transformer output leads, connected in such a way that I could apply positive current feedback to the circuit. When connecting a loudspeaker load, I was interested to see how a plot of the speaker terminal voltage would progressively flatten out and then invert as the level of current feedback was increased. As the feedback was further increased, the circuit would become unstable and oscillate.

I was somewhat surprised to see that you would use a Plitron output transformer in your circuit while not using full-loop feedback. To my knowledge, Plitron transformers, which are certainly first-class, have the best specs in terms of phase shift of any of the commonly available output transformers. One of the primary reasons why Crowhurst had suggested his circuit was to enable us to use output transformers of lesser capability.

In your op-amp simulation article (*aX* 12/03, p. 24), your balanced negative feedback goes to the cathodes of the input tubes. That is a fairly common connection and can be seen, for example, in some versions of the RCA handbooks of tube specs. In your later letter (*aX* 4/04), this seems now to be rewired to the plates of the input 12AX7s. You might try making some comparative distortion measurements since for most triodes distortion increases as the plate load impedance is reduced. That is what would happen in this hookup since the negative feedback opposes the signal at the 12AX7 plates. I've always thought a pair of pentodes such as 6AU6s would be better in that kind of connection. *aX*

FIGURE 2: 6L6GC UL plots B1.