Vacuum Tube Power Amp

continued from page 1

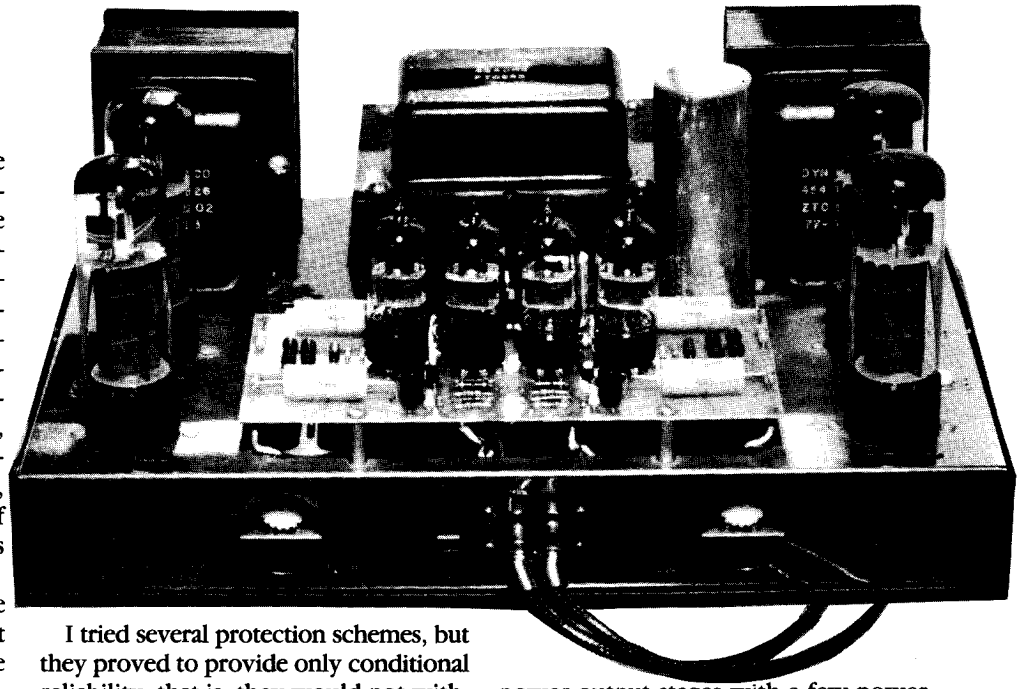
namics, and imaging.

The floating bias configuration of the regulators combined with the high voltage swing potential of the driver stage allows the circuitry described to be applied (with operating voltage considerations) to any number of basic tube power amplifiers. A description of the general application, however, would involve a discussion that would extend beyond the scope of this article. Therefore, I have chosen to describe a specific amplifier application. The Dynaco ST-70, widely available and a good source of high quality transformers, emerges as my candidate.

You might safely assume that the Dynaco ST-70 has been the recipient (and frequently the victim) of more modifications than any other commercial audio component. Ranging from capacitor upgrades in both the driver stage and/or power supply, to driver stage rework and rebiasing, most modifications are designed to reinforce the original design.

My design is much more extensive—using only the original transformers and hardware. I completely replaced the driver stage with an all triode design in which the voltage gain and phase splitting are accomplished within the same stage. The original power supply now serves only to input a bank of servo-controlled regulators. The majority of the circuitry is contained on two circuit boards, physically configured to reside within the ST-70 chassis (see *Photo*).

As you know from my previous articles, I am a strong advocate of highly regulated/servo-controlled power supplies. In prior designs, I used floating op amp, high-voltage regulators. These designs were both sonically neutral and extremely reliable. Direct application of this topology to the high-voltage/high-current requirement imposed by the output stages of vacuum tube power amplifiers results in a reliability problem. I identified the failure mechanisms to determine whether the original design could be protected or a complete redesign would be necessary.



I tried several protection schemes, but they proved to provide only conditional reliability, that is, they would not withstand some atypical but nonetheless possible situations, such as 3-second power line interruptions or shorted elements in the output tubes. I soon realized that a new regulator was necessary. After building and testing several devices, I finally devised a design that seemed insensitive to both line and load attack. I constructed several prototypes and sent them to various "real world" laboratories. The overall consensus was that the resultant regulator is not only more reliable, but sonically superior to the earlier design. Since then, approximately 25 copies of the version presented here have been built and perform without problems.

Since the output stage voltage regulator required development time, I took the opportunity to consider new driver stage "ideas brewing in the recesses." I auditioned a number of different topologies, including cascade and cascode inputs with split load phase inversion, and several variations of the "Williamson" circuit.

The constant current cascode differential amplifier emerged as the clear winner (and by no small margin). I refined this configuration through successive auditions and it now provides the greatest degree of dynamics, image and definition, in my experience. Independent reports from the field concur that this driver stage/power supply combination, when used with a Dynaco ST-70 transformer complement (*Fig. 1*) and operated within its power range, is sonically equal or better than commercial products costing up to several thousand dollars. As I previously mentioned, you can adapt this circuit to higher power output stages with a few power supply alterations.

The Driver

The driver stage's purpose is to provide a dual asymmetrical output signal of sufficient amplitude to meet the input level demands of the output stage. Balance must be preserved at both frequency extremes and be relatively insensitive to tube parameter differences, caused by aging and unit-to-unit variation. In addition, the circuit must be dynamically stable after overall loop feedback has been applied (if used). No single circuit configuration exists which is the best choice for meeting all these requirements; rather, the demands of the output stage must be factored into the choice of driver stage parameter optimization.

For example, for many years Audio Research used a popular technique of feedback around the output stage (transformer secondary to output tube cathodes). This reduced the distortion and linearized the output stage at the expense of requiring a greater peak voltage swing in the driver stage (which Audio Research provided). The indiscriminate application of this technique to a power amplifier, however, without the necessary correction to the driver stage (as has been suggested as a "general" improvement technique), may actually degrade dynamic performance.

To meet the voltage gain requirements two stages of triode amplification will be necessary. Given a choice of cascode or cascade, I have chosen the cascode configuration primarily because of its inherent direct coupling.

The lack of an interstage coupling ca-

ABOUT THE AUTHOR

Joseph Curcio received a B.S. in electrical engineering from Pennsylvania State University in 1971. He currently works for State of the Art Corporation in State College, PA. He has received two patents in electronic controls, and he is chairman of the IPC automation subcommittee and a senior member of ISA.