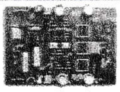


All FET Class-A 75W Amplifier

Starting life as a Borbely kit, this project goes a step further and utilizes an external power supply, normally associated with line-amps, headphone amps, and phono preamps.

By Rick MacDonald

While it is impractical (not to mention expensive) to power a Class A amp using batteries, it is, however, practical to build a separate power supply using umbilicals. Some of the benefits are obvious, but there are other reasons that some DIY builders may not have considered.

The idea for this project (**Photo 1**) began when I was listening to a headphone amp connected to a separate battery power supply. The sound of this amp was so quiet, with extended bass and very detailed mid and high frequencies, that I thought, "There must be a way to realize some of these benefits with an amplifier driving speakers, and not just any, but a full Class A amplifier." If I built this amp, it would need to be constructed from the beginning this way, and not just as an afterthought to solve problems with hum or other noise caused by transformers and their stray magnetic fields. It would need heavy well-made umbilical cables with connectors that are up to the task. With these things in mind, I decided to use a tested design for the amp and power supply, which brought me to the Borbely 75W Millennium.

DESIGN OVERVIEW

The basis for this amp comes from Erno Borbely's All FET Class A Millennium Amp (borbelyaudio.com). Intended to be built as two monoblocks, it can also be constructed as either stereo or dual mono, which is how I chose to build it (**Fig. 1**). With an array of ways to purchase it (you can buy the full kit, just the PCB, or almost anything in-between), I went with the PCBs and the semiconductors only; used my own sources for resistors, caps, and transformers; and also built my own enclosures. The amp consists of one driver board, one output board, and one power-supply board per channel. You can save yourself a lot of hunting for parts by ordering the entire kit, but if you are determined, I recommend getting the semis, as some may be tough to source, particularly the matched FETs.

The driver is an all-FET high-speed circuit with onboard regulators. Maximum supply voltage is ±55V (unregulated) and is adjustable from 30-50V. The unit can deliver 100W, but only 75W in pure Class A. Fully complementary, the input stage is differential cascode, using dual monolithic JFETs as input devices and MOSFETs as cascodes.

DC offset is tracked/controlled by the AD820, a JFET op amp powered by a shunt regulated ±10V supply. A relay out is provided to avoid the small turn-on thump (I used the direct out also provided). To handle any overly capacitive speaker loads, I used an L1R1 parallel combination on the output to control oscil-

PHOTO1: Front view of the completed amp.

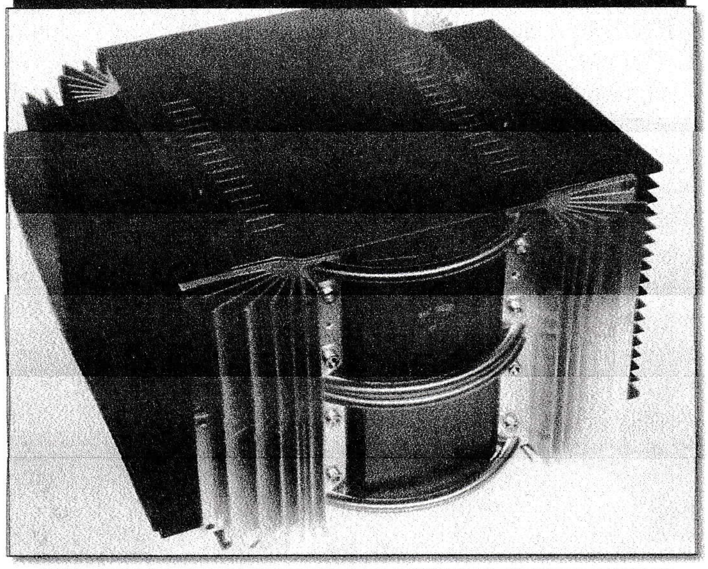
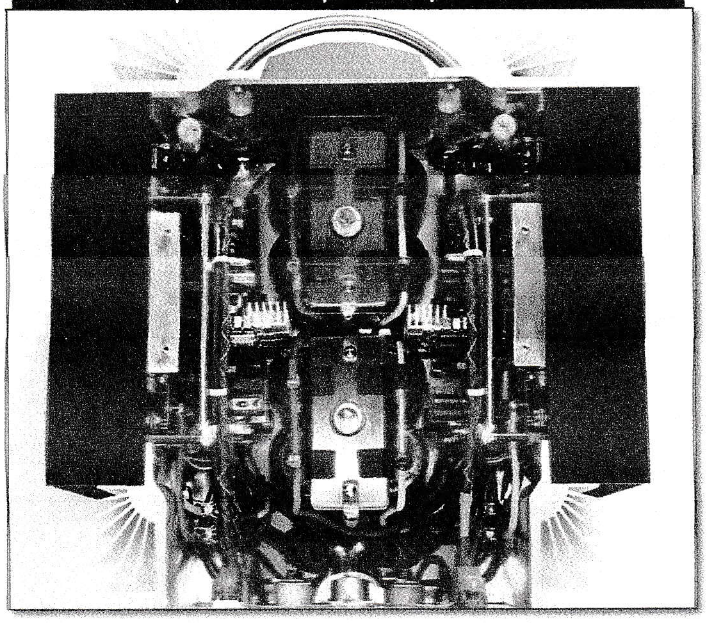


PHOTO 2: Top view of completed amp.



lations, but it is easily bypassed for lower damping.

The feedback network (called a T-network) was developed for the all-FET line of power amps. It accommodates both balanced and unbalanced operation, without changing the feedback network. A switch at the input equalizes gain in both modes, and ensures equal impedance for the two inputs.

The output stage uses eight pairs of TO-3P power MOSFETs (2SK1058/2SJ162), which come tested and matched, and this batch had the same lot code, which helps ensure good matching even with bias currents other than those used for the matching process. For this reason, no source resistors are required. The sole purpose of this circuit is to move huge amounts of current, and no voltage gain is introduced. These MOSFETs become very hot and must have significant heatsinking to run Class A.

As you can see in **Photo 1**, the enclosure provides just that . . . in abundance. The big horseshoe-shaped heatsink (**Photo 2**) makes a good strong chassis. Vertical corner sinks supplement the horizontal fins of the main heatsink (black). For reasons of assembly and other design issues, it was the only way they would all fit together. Considering the enclosure was built using available parts, surplus heatsinks, and scrap pile aluminum, it came out reasonably well.

The power supply is simple, consisting of independent supplies for driver and output stages and including delay timers for power-on and speaker relays. The main power caps are separate from the kits, and 100,000μF per rail is recommended. I used NTC thermistors on the power-supply board to reduce inrush current, and you can order transformers along with the kits. I used separate surplus transformers (for driver and output boards) on this project (625VA—minimum required).

WHY EXTERNAL POWER SUPPLY?

The most obvious benefits—reductions in noise, hum, and EMI—have been proven in line and headphone amps. AC mains can bring in all kinds of garbage picked up along the way. Microwaves, RF, and switching power supplies all contribute to the hash that can cause

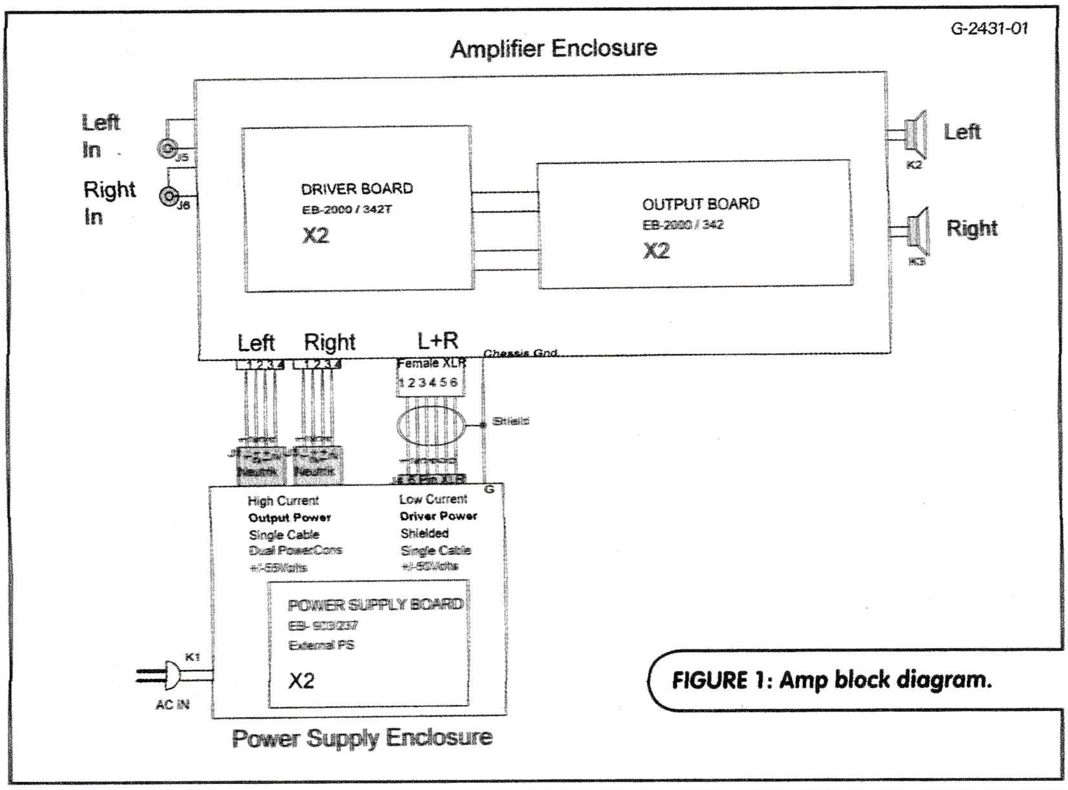


FIGURE 1: Amp block diagram.

problems in audio gear. Removing the power supply from the amp and away from the high voltage gain of the driver stage can have beneficial results similar to using a battery supply.

The lowered noise and audible improvement in the final amplifier's sound outweigh very minor losses in channel separation. And because most of the reservoir caps are in the amp chassis, high current demands are met, and minuscule losses due to umbilicals are overcome. This works because approximately one-third of the filter caps (90,000µF) are in the power supply, while the rest (200,000µF) are in the amp (**Photo 2**). Combined with the 2m umbilicals' small inductance and resistance, a pseudo pi network is produced, helping to attenuate any residual ripple or noise, essentially making the cables part of the power-supply design.

Less obvious are the benefits to DIY builders. This power supply will be used on several other different amps, some MOSFET, some bipolar, all with different topologies. Up to half the cost of building any amp is its power supply. This will save time and expense when experimenting with other designs. But even more important, eliminating the power supply as a variable will give you insight into the amp's subtleties, by knowing that changes in amp design alone have caused improvements (or not) in sound and performance.

Because there are no transformers in the amp's chassis, it is much lighter and easier to move, and transformer-induced hum is eliminated. Placement of the power-supply unit is flexible so it can be put on the floor out of the way or hidden. While working with these power-supply voltages imposes some limitations, you can use methods such as regulation and others to adjust them to required levels.

OUTPUT CONSTRUCTION

Start with the output boards, which I constructed first and mounted to the main heatsinks (**Photo 3**). This gave me the dimensions needed to mount the drivers on top and also gave me an idea as to the size of the enclosure. Because of the integral nature of the output modules, drilling and tapping were done first. I soldered in all passive components and left the MOSFETs unsoldered until the last step. Using the stuffing guide as a template (**Photo 4**), I marked and tapped all holes on the heatsinks. This included measuring and tapping four holes for the driver board mounting plate.

You must take care in the final step when soldering in the MOSFETs. You must bend and test-fit leads onto the mounted boards before soldering. Tighten the MOSFETs down first (with silpads!), then solder them in last to avoid putting pressure on the devices or their leads. Because all parts (semis

PHOTO 4: Stuffing guide used to mark MOSFET holes.

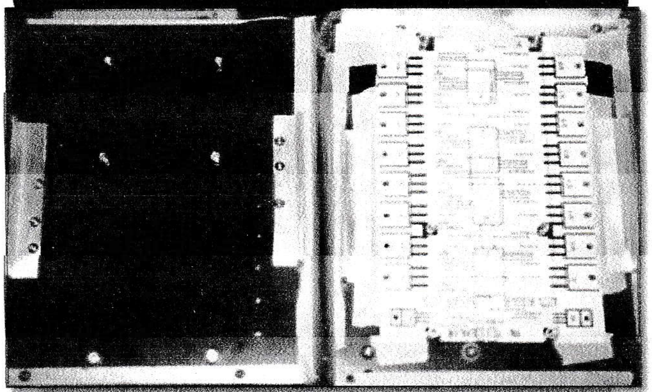


PHOTO 5: Completed driver.

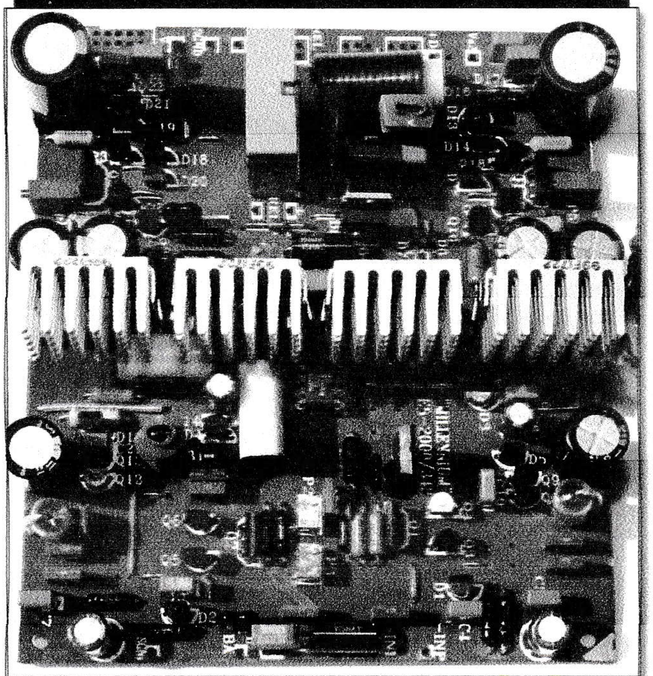


PHOTO 3: Output boards mounted to heatsinks.

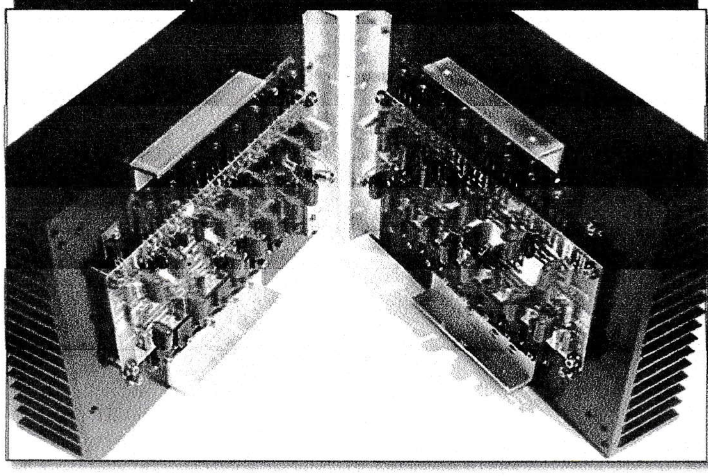
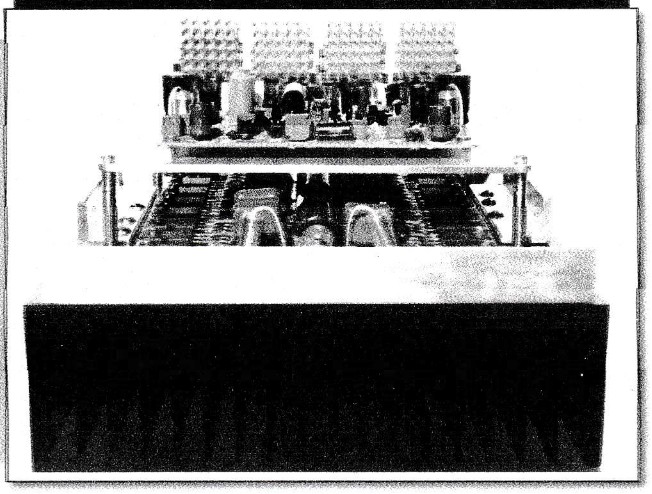


PHOTO 6: Driver and output mounted to heatsink.



in this case) are clearly labeled and placed in their own plastic bags, sorting and keeping track of what you are doing and what needs to be done is made that much easier.

DRIVER CONSTRUCTION

This PCB requires some degree of skill in soldering, and might be beyond the weekend builder. But if you have military or other soldering experience, you should have no trouble. You can purchase these PCBs as either standard fiberglass (FR-4) or Teflon (more expensive). Because of Teflon's excellent heat resistance and dielectric properties, I used it here for the driver board (**Photo 5**). The stable dielectric properties benefit this circuit because of the high gain that takes place and therefore have a more significant effect on the sound. Along with the PCB and semiconductors, I also received the relay, the inductor coil (L1), and the TO-220 heatsinks.

The rest of the components are made up of Vishay, Holco, Caddock, and Dale RN60 resistors. Cerafine, Wima, and Blackgate caps make up the bulk of the caps. The heatsinks provided are adequate, but I modified them by mounting crosscut sinks designed for a video chip (**Photo 5**). I attached these using 440 screws and thermal epoxy (Arctic silver).

There are two reasons for this: First, the boards will be mounted on their sides, reducing the cooling efficiency of the standard sinks (new ones are crosscut and work well at almost any angle). Second, I will be trying higher bias currents, with various other changes, and want to avoid heat stressing the MOSFETs (**Photo 6**).

The driver is a fairly complex PCB—some traces are thin as well as close and must be examined for solder bridges, splashes, and small metal objects, which could short these traces together. I recommend using a small handheld blue LED flashlight, which is popular and widely sold. Just make sure it uses the blue (I believe near ultraviolet wavelength) LED. After virtually inspecting with white light, I use the blue light to illuminate small particles and other debris missed by the first inspection. Blue light also illuminates cold joints and flux residue missed by other visual methods.

MOUNTING THE DRIVER

Once this was completed, I mounted the driver to the main heatsink (**Photo 6**), above the output board on a 5″ × 6″ aluminum plate. I installed insulating plastic (stuff used in switching power supplies) directly under the driver PCB to avoid any accidental shorting. On the bottom of the driver's aluminum plate, I installed a ⅛″ thick silicon steel plate roughly the size of the driver board to increase shielding from the output board directly below it. High currents run through the output board and induce electric fields that can cause problems on the high gain driver circuitry when it's that close. You can't see the plate from the photos, but it's there.

RESERVOIR CAPS

Because even Class A circuits draw more current on peaks, most of the power caps are placed in the amp itself. Not wishing to use the three leg brackets typically used to mount caps, I devised a way to mount them that also serves as the ground bus (**Photo 7**). I picked up these solid copper brackets (**Photo 8**) from a metal recycler and cut them to hold two banks of four caps.

PHOTO 7: Copper Gnd bus.