Rodney E. Cavin

MOSFET MOD FOR THE DYNA ST-120

This article describes an upgrade for the Dyna ST-120 MOSFET modification (TAA 3/92), providing currently available transistors, the original author's new parts values, and some useful construction techniques for this highly satisfying amplifier.

The fate of my old Dynakit Stereo 120 was in grave doubt (one channel noisy, the other oscillating) when Kenneth Miller's *TAA* 3/92 article arrived. It described a simple upgrade to a modern design, using a JFET input and MOSFET output devices while still meeting all of Dynaco's original specifications. Fate would spare the old ST-120.

Years passed, however, before that issue of *TAA* surfaced again, from under a pile of other projects waiting on my desk. Still, it presented an opportunity to try a MOSFET design without having to start from scratch. Why not? Isn't that part of what this hobby is about?

The other part is listening. The mod was well worth the effort—smooth, tight, and honest, with no noticeable "sound" of its own. It was an excellent, modern, high-end amplifier hiding in the body of a 30-year-old classic (*Photo 1*)!

PHOTO 1: The old classic, but almost everything under the hood is new.

Discontinued Parts

However, device obsolescence had taken its toll, creating new challenges for a once-proven design. Meeting those challenges was an experience I shared with Ken, who was helpful beyond reason as I forged ahead.

This began when I discovered the N-channel output MOSFETs were no longer available. I found what looked like a nice substitute pair, but, unfortunately, they proved unsuitable, requiring a considerable bias increase to overcome their crossover notch distortion, which lowered their output-power capability.

I wrote to Erno Borbely, whose amplifiers used the same outputs, and to Ken, to see what suitable devices they'd found currently available. Both responded quickly. Erno suggested several pairs, with some helpful information about them. Ken still had some of the original type but, he, too, would soon face the problem of obsolescence.

I decided on 2SK1058/2SJ162 output pairs, suggested by Erno, which are internally the same as the original types, but in a plastic TO-3P case. Because of the plastic, they have a slightly lower power dissipation than the metal-cased originals. This wouldn't be a problem. Ken had already told me that only one output pair was needed for an 8Ω load, but that two pairs were necessary to drive a 4Ω load. I opted for the two pairs for load flexibility.

I quickly discovered that most of the other devices in Ken's circuit were also no longer available. Moreover, from Motorola's excellent website, I learned that it had discontinued its entire MPSU line. Ken began researching this problem and came up with new devices and some circuit changes to support them (see sidebar, "Replacing the Obsolete").

Chassis Mods

I forged ahead with great enthusiasm, planning changes more extensive than Ken's new amplifier cards. I cleaned off the old chassis, replacing the original chassis parts with new ones. Since I like maximum control with grounding arrangements, I added a small switch to lift the new, three-wire AC cord ground, if needed.

On the other end of the chassis, I added a five-way ground terminal to allow chassis exterior grounding where and as needed. Such flexibility in grounding schemes is particularly helpful to tune a system for minimum hum when it includes devices utilizing internal grounding to the neutral side of the line, and other such commercial schemes.

I also replaced the original RCA-type input jacks with some high-quality ones from Old Colony, leftovers from an earlier project. The new output terminals would be K.E. Lang's Ultimate Speaker Connectors (nice, solid-brass 30A six-way binding posts, with noncaptive thumb nuts, which accept flat-ring terminal lugs).

The power transformer was good, but C12 and one of the output C7s had lugs broken off, with the old leads soldered to the rivets at the lug base. Who built this? That certainly wouldn't do in a new amplifier!

Fortunately, we have here in central Florida a builder's heaven in Skycraft

About The Author

Rodney E. Cavin became an audiophile at age 8, when, after buying a windup phonograph, he tried to make it louder and sound better. A graduate of DeForrest's Training and Navy electronic schools, he began in radio and TV engineering, worked in electronics development at Cape Canaveral, and then went into TV and film production. He currently does audio and video work for business conventions. He also writes film scripts, occasionally directs, and continues building amplifiers and speaker systems to make them sound better.

Parts, a surplus electronics (and other parts) store. A little shopping, and I had replacement capacitors, but they were slightly taller than the English-made originals. Their height would put the screw terminals within spark-gap distance of the top cover.

Since I planned to use new ¾″-high rubber feet under the chassis, I found the needed room below. I nibbled somewhat crude holes in the chassis to allow the capacitors to extend below it, providing ample clearance between the terminals and the cabinet top.

PHOTO 2: The covered mono version built on a commercial chassis.

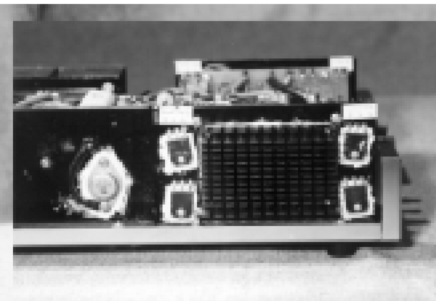

PHOTO 3: The TO-3P MOSFETs with the killer blocks on the original heatsink.

The chassis didn't clean up as well as I'd hoped, so I had a plating company strip it, then nickel and chrome plate it. I painted the top cage flat black to complete the popular color scheme. I managed to preserve the Dyna logo, a reminder of the amplifier's heritage. How could this new design, sporting a chrome chassis, fail to live up to expectations?

Next, I planned my parts needs. Most of the capacitors came from Welborne, along with ½W and larger resistors. The output MOSFETs came from MCM Electronics, and the rest from Newark Electronics. Two of the values in ½W resistors were not available in the resistor series from Welborne, so I doubled the value and paralleled two of them, using the ¼W, 1% resistors from Digi-Key. I filled a few of my capacitor needs from Skycraft, quality names I recognized from previously purchased Old Colony kits.

Making the PC Boards

I planned to make my own PC boards using the copier technique with TEC-200 film from Welborne. While it's possible to use the circuit view provided in Ken's article, I would need to reverse it to use the film process, which would make the final film a second copier step, or another generation, away. (Now that I've made a few boards with the film, I see that the extra step probably would not cause much image degrading.)

I also wished to rearrange the pads to accommodate some of my new parts (for example, a good tubular 6.8μF instead of a minielectrolytic) and to make larger pads, because they hold up better for the parts changes that are sometimes necessary in home-builts. I also duplicated a couple of pad pairs so I could use different-sized parts, depending on availability.

I started with Welborne's Assist program. Laying out boards is easy with this DOS computer program, but be aware that an HP Laser printer is necessary for final printing. I have an inkjet, which the program doesn't scale properly. Since the program allows you to draw schematics that you can convert to board layouts, it is an excellent one. I hope Welborne upgrades it to allow more selection in printers.

I finally turned to TurboCAD, an easy-to-use CAD program for Windows that I already possessed. I laid out the board from the component-side view, which gave me the proper final view for using film to transfer to the PC-board copper. This program also allowed me to add mirror images of lettering, which would read correctly after I flipped the film to transfer the resist pattern to the copper.

To provide for two boards on a standard 8½″ × 11″ film sheet, I used the CAD program to copy a second board image below the first. I printed it on my inkjet, then using a copier, transferred the page to TEC-200 film, which I used to heat-transfer the resist image to the PC board. Making your own PC boards is really an easy process. If I can do it, so can you.

Mono Transformer

At my surplus-parts supermarket, I had discovered a power transformer very similar to Dyna's original, so I decided to make a mono version. It would be my Dolby center-channel amplifier and also serve occasionally as a speaker-test amplifier (*Photo 2*).

Being a fan of heatsink overkill, I found some high-dissipation sink blocks, which I centered on the original Dyna sheet metal. They're really unnecessary, but they give the output stage a killer look, and they barely feel warm when the amplifier is pushed.

The TO-3P case design of the new output MOSFETs requires different mounting holes than Ken's, or Dyna's, original TO-3-style devices. In case you're not familiar with them, the TO-3P devices look like oversized TO-220 devices: one mounting hole, and three holes (or a slot) for the leads if you plan to poke the leads through the heatsink (*Photo 3*).

I drilled mounting holes for two MOSFETs on each end of the brackets, skirting around the original TP-3 mounting holes. When drilling the new mounting holes, be sure to remove any burrs around the holes which might cut into the mica insulating washers that you'll mount between the MOSFETs and the heatsink. I find a gentle hand twist from a sharp, oversized drill bit does a nice job.

I mounted the MOSFETs on the same side of the heatsink where the original devices were located, using a plastic shouldered washer between the mounting screw and the device, and a TO-3P mica insulator between the device and the bracket. Placing a generous coating of silicon heatsink compound between the MOSFET, insulator washer, and bracket is a necessity.

You may prefer to mount the MOSFETs on the inside of the brackets, which would require drilling only a mounting hole, thus eliminating holes for the leads. I did this in my mono version. As a custom builder, it's your choice. I bent the leads of the MOSFETs at right angles to protrude through the heatsink. Short pieces of Teflon® tubing on each lead prevents shorting to the heatsink.

Wiring Advice

A few words about wiring: I have become a firm believer in the Walt Jung approach to high-quality wiring (see "POOGE-2," *TAA* 4/81, p. 9ff), namely, using a number of #24 wire-wrap wires paralleled in a Litz-type approach (*Photo 4*). It costs a little more, but is more commonly available than when Walt's article first appeared.

For PC boards, I usually twist the ends together, enlarging the pad holes as required, and solder in the usual manner. However, it's more practical to make small loops of all the individual leads for attachment to the MOSFET leads (*Photo 5*).

If you use ordinary single-conductor solid or stranded wire, be sure to obtain solid-copper wire. Much of the common hookup wire today is plated steel. In view of the audio quality you are attempting to approach in these projects, don't handicap them with poor wire!

In any case, you need some method of clamping the MOSFET wiring to the heatsinks to relieve strain on the thin leads of the plastic devices, which could easily break off (*Photo 6*). Ken used a different approach. He mounted tie-point strips at the MOSFETs to junction the device leads to circuit wiring. This is an even better strain relief.

I tested the power supply with the two 300Ω 7W resistors from the old boards—in series, as Ken suggested. Note that you must use a minimal load on this power supply to bring it into its regulatory range. With no load, the output will be a few volts high.

Although providing 72V, my old supply was poor on regulation, so I replaced the transistors. Again, the original transistors are nearly impossible to find. The common TIP31C and TIP32C transistors became replacements for Q8 and Q7, respectively. Several choices are possible for Q9, including the readily available 2N3055 and the MJ802. You can also use one of the former NPN output transistors for Q9, as I did.

My power supply was still soft. After a little troubleshooting, I discovered the problem to lie in some of the original diodes, so I replaced them all. I used 1N5404s (3A 400 PIV) for the 3A original diodes, D4–7, and 1N4004s for the 1A diodes, D8, 9, 11, and 12, all easily obtained.

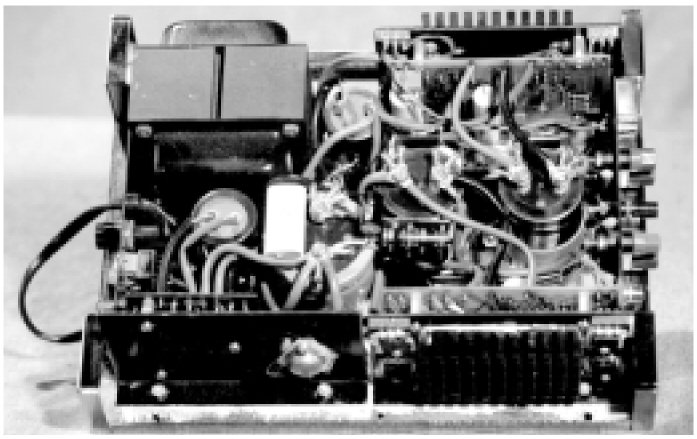

PHOTO 4: Inside the modified Dyna ST-120, showing the Litz-type wiring; not as pretty, but sounds good.

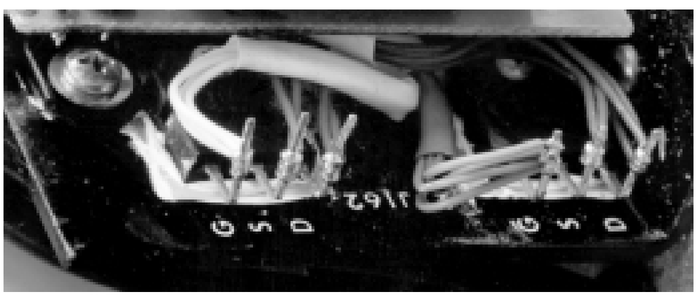

PHOTO 5: How the multiple wires of the Litz-type wiring are attached to the MOSFET leads.

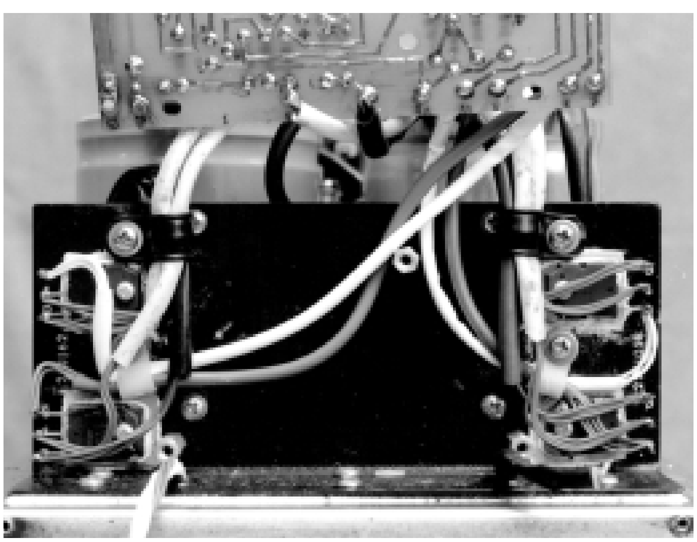

PHOTO 6: With the PC board raised, the method of clamping leads to the heatsink is visible. The killer heatsink fins are on the back side.

New Zeners

With all else being new, I replaced the zener, D10, on general principles. As 58V zeners are no longer common, I installed a 1N4758A (56V, 1W) zener. It provided good regulation and—with Ken's modification of R21 to 1.8kΩ—82V.

In my mono version, I used a 1N4759A (62V, 1W) and lowered R21 to 1.3kΩ. This arrangement gave somewhat better regulation than the zener/resistor choice in the stereo version, and yielded the same output voltage. I also needed to increase R26 to 47k. Both changes were required by the slightly higher secondary voltage of my new power transformer.

Next I completed the amplifier PC cards, following Ken's check-out procedure (*Photo 7*). These simple checks confirm that the cards are in working order. Time spent here can save an investment in output MOFSETs, the most costly part of this modification.

Since I'm usually behind in my building, I like to scan subsequent magazine issues for letters and error corrections. Doing this, I found a note (*TAA* 2/93) about the diodes in Ken's article schematic. This correction is wrong! The diode polarities are correct as originally published. A quick look at the circuit, and reading Ken's thorough description, makes it obvious.

In accordance with a fairly common audio modification, I also added bypass capacitors, 5.0µF and 0.47µF polypropylenes, across C11 and C12 in the power supply, and across each channel output capacitor, C7. I've been doing this automatically since reading of the technique in *TAA* years ago. Again, it's a personal choice.

As another personal choice, I added 0.01µF, 400V disc capacitors across

Replacing the Obsolete

By Kenneth P. Miller

I'd like to thank Rod Cavin, as well as all the other *AE* readers who've built my mod, for their favorable "reviews" of my redesigned ST-120 amplifier. Such testimony confirms that my project is a cost-effective conversion, fun to build, and easy to listen to.

All the details of modifying the amp were published in the 3/92 issue of *TAA*. If you try to modify your ST-120 from the original article, you'll find, as Rod has mentioned, that the output transistors called for are no longer available, and that the driver transistors have become not only difficult to obtain, but unreasonably expensive.

I have found solutions for both of these problems. Unfortunately, the replacement output transistors I suggest are not direct, plug-in substitutes for the original devices, and they do require a bit more voltage drive than the original circuitry could supply. I was able to supply this extra drive without changing the circuit topology, so the schematic diagram, the theory of operation, and the printed-circuit-board layout remain unchanged.

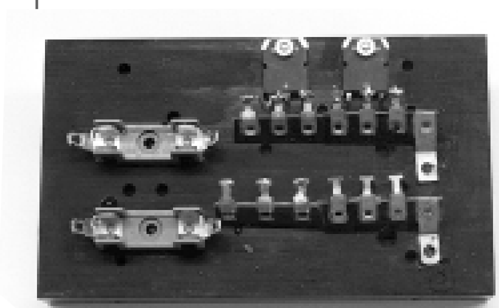

PHOTO 8: Arrangement for supporting output transistors.

Most of the construction details and all the PC-board tests given in the original article still apply. Obviously a completely rewritten article describing these changes is unnecessary—a simple "revis-it" should do. So my comments here focus primarily on the differences between the "new" and "old" modification.

Parts Changes

First, the parts changes. Q106 and 107 are now 2SK1058 transistors; for Q108 and 109, use 2SJ162. Here are their pin-outs: hold the transistor so that you are facing its mounting flange, with the pin leads pointing down. Then, from left to right, the leads are drain, source, and gate. The resistor changes are all regular carbon composition, 5%, ¼W units: R107, 7.5kΩ; R110, 220Ω; R111 and R112, 10Ω; R113 and R114, 110Ω; R115, 4.7kΩ. R18 should be replaced with a 10Ω, 1W resistor. C109 is no longer used.

Driver transistors Q103 and Q105 are MPS-U60, and Q105 is an MPS-U10 in the original amplifier. These transistors have become next to impossible to obtain. If you can't find them, substitute MPS-U57 and MPS-U07, respectively. These are the preferred substitutes, because they have a built-in heatsink tab and use the same pin-out. MJE-253s for Q103 and Q104, and MJE-243 for Q105 are also acceptable substitutes. However, these latter devices require you to attach small heatsinks, and their pin-out is different. Facing the metallic side of the MJE transistor case with the leads pointing down, the pin-out is—from left to right—base, collector, and emitter.

The input JFET transistor, a 2N3821, is still available, but scarce. An acceptable substitute is the 2N5457. Facing the flat side of the transistor case with the leads pointing down, the pin-out for that device is drain, source, and gate, from left to right. You may also use source, drain, gate as the pin-out for this transistor, since the source and drain leads are interchangeable.

The location of the output transistors on the heatsink is not critical. More important is to supply some kind of mechanical support for the soft leads of the plastic MOSFETs. I used a seven-terminal tie-point strip, with six of the tie points supporting the leads of a pair of transistors, while the last one fastened the terminal strip to the heatsink. Thus it took four of these terminal strips to do both channels of the amplifier (*Photo 8*).

A Wise Move

I also recommend that you fuse the output transistors to provide some measure of protection in the event of a short circuit or reduced impedance load on the amplifier. It is well known that using a fuse to protect bipolar transistors is an exercise in futility, and I simply assumed this would also apply to MOSFETs. I've since found, albeit accidentally, that this is not necessarily so.

I use one of my modified ST-120s for loudspeaker and crossover network testing, and such use leads, sooner or later, to an unintended short circuit, despite all care. Wishing to protect something in the amplifier, if only the power-supply diodes, I installed a fuse between B+ and the output transistors. Not long after came the moment of reckoning. A wire fell off a crossover network I was fiddling with, I saw a small spark, and the amplifier went dead. Troubleshooting the amplifier produced nothing more than the blown B+ fuse. So I replaced the fuse, powered up the amp and, to my utter surprise, the amp worked as good as new.

each main rectifier diode, soldered directly under the diodes on the circuit side. It's probably unnecessary, but I feel better knowing I've done all I could to prevent possible power-supply noise problems.

Testing

After finishing the final wiring, I mounted the output heatsinks to the chassis using a generous amount of silicone compound. It was then time for the smoke test. All was normal. After 20 minutes, the main supply voltage settled at 82V across C12. The positive side of C7 was between 41 and 42V, almost exactly half the supply voltage. The +V supply across C11 was about a volt below the main supply. All was cool, quiet, and smoke-free!

In bench checks, both channel measurements were virtually identical, supplying 60W into 8Ω and 103W into 4Ω, just at the point of clipping. Both channels driven together supplied 58W each into 8Ω before clipping—indicating the current limit of the power supply. Quite good for a pair of 60W amplifiers on a power supply good for 175W, or a little over 2A at 82V. This is no problem, since you never listen to maximum-power sine waves in audio.

The frequency response measured ±0.2dB from 20Hz to 20kHz—smoother than I'd ever experienced before. The upper end starts falling around 72kHz, because of the input low-pass filter circuit. I can see a solid, level response below 5Hz on the low end, but measurements in this range are beyond reliability with my test equipment. This amp will reproduce it all, very nicely.

The living room was the next test. Mine is about the size of a typical apartment living room. I drive Jordan System Five speaker systems, with modified crossovers, which I've used since I built them in 1985. I've had several power amps online during that time, including a Dyna ST-150 in its original state, and later in a highly modified form (from *TAA* pages), as well as Heath's last power amp, the AA-2500—actually a Harmon Kardon in kit form.

A Smooth Mod

I can honestly say that Ken's modified ST-120 design is the smoothest, most natural, open amplifier I've heard in my listening room. It doesn't seem to have any "sound" of its own. If you have a very large room and like to play synthesizer-created music—with high-level square-wave content at ear-bleed levels—you

Since then I've installed fuse protection in all my prototypes with excellent results. Here's how I did mine. I installed a pair of Radio Shack chassis-mount fuse holders (#270-739) on each heatsink. I tied the drain leads of the N-channel output MOSFETs together at one end of the fuseholder, and wired the other end of the fuseholder to B+ at C12. The drain leads of the P-channel output MOSFETs are likewise tied together at one end of the second fuseholder, with its other end wired to the grounded side of the output-speaker jacks.

I feel a bit sheepish to admit this, but since adding fuse protection I've had another half dozen or so unintended short circuits across my speaker-testing ST-120, and it has so far survived with no more damage than the blown fuses. You should understand that I have not run any controlled tests to verify this as foolproof protection under all circumstances, nor can I say that you can protect other MOSFETs with a fuse. All I can do is pass on what I've discovered and encourage anyone building this amp to incorporate this into the modified ST-120.

The additional expense and effort of adding the extra parts is trivial compared to the cost of replacing blown output transistors. And if my transistors are good but degraded, I've not been able to detect this, since the amp still meets its original specifications. What type and size fuse to use? With an 8Ω loudspeaker, I use Radio Shack #270-1009 fast-acting 3A fuses. With 4Ω loads, I use #270-1011 fast-acting 5A fuses.

Ensuring Reliability

One of my reasons for modifying this amp was to improve its reliability. Before I submitted the modification for publication, I purchased and modified as many ST-120s as I could afford (three) in order to ensure that its performance was consistent from unit to unit. Those prototypes were completed in 1991, and all three are still in use today. After nearly seven years of continuous use, none has required servicing of any kind—except for my speaker/crossover testing unit, which blows a protective fuse whenever I get careless. Obviously I believe I've solved the reliability bugaboo that plagued the original Dyna design. Although the "new" mod uses different output transistors than the prototype, I'm confident it will hold up just as well as the "old" one.

should look for a bigger amp. In the world of real music and film sound tracks, this amp is more than adequate.

If you have an original ST-120, this upgrade will be very satisfying both to build and to hear. For about $200 and some time, you will have a quality amplifier, comparable to a manufactured one costing many hundreds of dollars more, and possibly sounding better—and it will be many leagues beyond what's at your local consumer-electronics store.

Or maybe you'd like to build your own from scratch. Finding a suitable power transformer will be the big challenge. My surplus find was a Triad F49U with two 36V 3A secondary windings that I wired in series. You'd need to find something around 70V at 2A, perhaps one of the new toroidals. Either way, what's important is that you built this amplifier! ■

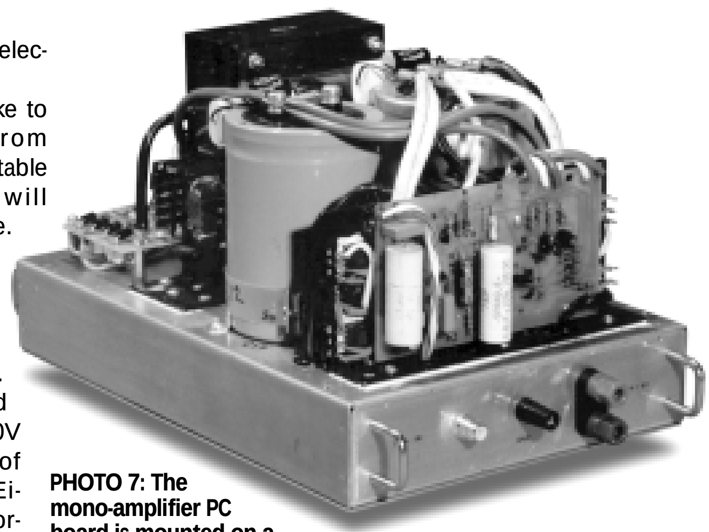

PHOTO 7: The mono-amplifier PC board is mounted on a heatsink in a way similar to that of the board in the original ST-120.

Sources

Digi-Key Corp.
(800) 344-4539, FAX (218) 681-3380
Website http://www.digikey.com
Resistors

IMSI
1895 Francisco Blvd., E., San Rafael, CA 94901-5506
(415) 257-3000
Website http://www.imsisoft.com
TurboCAD

K.E. Lang
6501 Lancret Hill Dr., Austin, TX 78745-4713
E-mail: Bat.L@usa.net
Ultimate Speaker Connectors

MCM Electronics
(800) 543-4330, FAX (937) 434-6959
Website http://www.mcmelectronics.com
MOSFETs

Motorola Semiconductor
http://www.mot-sps.com/sps/General/chips-nav.html

Newark Electronics
(800) 463-9275
And many local area offices

Old Colony Sound Lab
PO Box 876, Peterborough, NH 03458
(603) 924-6371, FAX (603) 924-9467
E-mail: custserv@audioXpress.com

Welborne Labs
PO Box 260198
Littleton, CO 80126-0198
(303) 470-6585, FAX (303) 791-5783
Assist program; capacitors