

# POOGE-2

## A Mod Symphony for your Hafler DH200 or other Power Amplifiers

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WITH SPECIAL ASSISTANCE FROM  
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### INTRODUCTION

WHEN WE FIRST SAW the Hafler DH-200 our impression was; here's another moderately-priced kit that will be popular with audio amateurs because it is perfect to modify. There are now many DH-200's in circulation, many with the expected modifications, David Hafler and Ed Gately have given us another classic, a solid-state Stereo-70. Thanks!

After reviewing the DH-200<sup>1</sup> WJ began a series of improvements to that review sample (SN3933833), with comparison against an unmodified unit built from a kit (SN3018009). These mods began with simple capacitor changes, recommended in<sup>2</sup> and grew into a larger scale examination of virtually everything in the unit, save the basic topology. It is gratifying to note that others<sup>4</sup> have reported the usefulness of our suggested capacitor improvements<sup>2</sup> which generally agrees with the correspondence we've received since that article. Pat Amer and Jim Boak have employed those concepts, as well as an improved version of Jim's regulator, in their Stereo 150 mod articles<sup>5,6</sup>

With another pair of factory wired DH-200's provided by the Hafler Company, DM modified one unit with the changes below (SN3026946), for comparison to a stock reference unit (SN3026950). Comparative listening tests were done in the fall of 1980 by J. Peter Moncrieff for his IAR "Hotline" (IAR, 2449 Dwight Way, Berkeley California 94704). The intent was to document that the sound of the Hafler could be improved with changes independent of circuit topology, and to provide the public with an independent subjective assessment of the modified unit, by an acute audio equipment reviewer. Other key participants in the project were colleagues John Civitello, Rod Rees, and Don Spangler who not only performed corroborative work overall, but more

significantly, contributed specific creative inputs of their own to the project, each in his own way. This article is concerned with both the theory and execution of the changes.

What may not be obvious from a quick read of this article is the background, motivation, and rationale behind it. This effort picks up where the POOGE-1 article concluded<sup>7</sup>. It applies the concepts articulated there, plus much more, to a popular power amp. For those unfamiliar with that article, we suggest a reading, or re-reading, because we don't plan to repeat all of its detail. To summarize briefly though, given a topologically "correct" circuit: tube, transistor, or IC, audio-ideal resistors, capacitors, contacts and power supplies will allow that circuit to perform optimally (or, to the maximum capability of a given topology).

In the case of the DH-200, we re-emphasize the importance of passive components and power supply regulation on sound quality. However, this time we add (and/or amplify) other key variables to the equation of sonically relevant factors, namely: contacts, conductors and wire: their metallurgic and insulating materials, composition, and configuration technique. We go into more thorough detail below, but for now suffice it to say we consider *metal contacts*, *conductor composition*, and *wire composition and wiring technique* of equal importance to the factors above. These things are necessary ingredients for good sound, whether inside or outside amps, preamps, or speakers. In other words, for good sound we need good components and good conductors throughout the signal path, including (perhaps most importantly) points within components, as well as their interconnections.

A common denominator of the generally new theoretical areas within this article is the metallurgy of audio signal conductors, which will be seen to have measures of influence in three different contexts. Conductor contacts certainly have been previously discussed, but here new considerations and background are introduced. *General conductor considerations* for

all components have seen little discussion, but interconnecting wires have. We hope this discussion will bring considerable new insight about both metallurgical and magnetic behavior.

Anyone following audio discussions (here or elsewhere) can see little unanimity on the issue of whether differences can truly be heard between audio amplifiers. Golden ears consistently report hearing differences that meter readers just as consistently fail to find in their double-blind, short-term A/B tests. What could be going on to give rise to this situation? Can any plausible explanation be offered for such a deep and continuing schism, or, could it be due to methodological and/or perceptual phenomena? (See Rees & Shaeffer, TAA, 1/81.)

Surely, such strong and continuing differences of opinions must be based on some fundamental differences in assumption or approach. While this article will not attempt a full explanation, it should provide some further insight into the possibilities, and certainly will offer conceptual tools and analytical insight for further investigation.

For example, if one accepts the premise that virtually all circuit level electronic components can introduce to audio both sonic colorations and masking effects (not only in various degrees, but in combinations perceived differently) then it is obvious how hard it is to isolate the various distortions and colorations in the chain from cartridge to speaker. With any audio system one hears only the final output from the speaker, but the sound we hear is actually a *composite*; a series of interactions of *multiple hierarchies*, both *linear and non-linear*, between cartridge, turntable, cabling, preamp/amp, speaker; between each and every capacitor and resistor, each and every conductor and contact, and, finally, between the system and the room.

So, if one wants to say what the "sound" of a preamp or amp is, one can really only say what it is in the context of a specific situation, with appropriate qualifiers for related gear, room properties, even the tastes, train-

ing, and experiences of the individual (see Rees, below). Peter Moncrieff's "M" Rule<sup>9</sup> gives a caveat on making evaluative assessment of a component, and is really only proper logic towards an ideal evaluation. In it he states "No evaluation of a device can be scientific if that evaluation is carried out through other devices that are imperfect." We take the term scientific to here mean *systematic and exact*.

In sonic language this can be interpreted to mean that we cannot come to absolute conclusions about any component in a system containing other than perfect components. Unless we can somehow make all of them perfect except the item under study, we are caught in a chicken-and-egg paradox. Indeed, how do we make all of the rest perfect, when we are still learning to minimize the defects of one? (Defects which are common, to some extent, in all.) Very simply, we can't. But, in practice, the alert audiophile can iterate towards overall improvement, bootstrapping everything along, re-evaluating for relative improvement periodically. He can A/B against a reference (unmodified) unit, and make frequent comparisons to the real thing: live, unamplified music. Corroborative duplication by others can enhance the credibility of individual experiments.

Systems can and do change in sound character as components are changed, and many interaction mechanisms exist which are poorly understood. We have all heard of the speaker or amplifier which is "more revealing" of the signal. Understand of course that more revealing has two contexts—more bad things in the signal, as well as more good things (see Hiraga<sup>8</sup> for example). Considered as an execution which incorporates all of the suggestions which follow, a DH-200 transformed into the POOGE-2 can reveal more good things from your records and other sources, but you should be prepared to observe that it can also reveal previously masked defects as well. This caveat leads into the potential impact these recommended changes may have on the remainder of your system.

Considered as a sequence, this phenomenon of improvement in detail which un.masks lower level defects not previously perceived separately can of necessity (ultimately) encompass *all* of your system, unless it is otherwise already perfect. Work on the amp awhile, then you can reach a point of diminishing return where the level of resolution is limited by the preamp, speaker, or whatever. This happened during this project several times to different participants, at different interfaces. It appears that wiring of various points plays a large part in this masking/unmasking process. Note that J. Hiraga described his experiences along these lines as far back as 1977<sup>8</sup> Once you perceive for yourself what the sum of these total changes can do for your sound, you may believe it is only logical to incorporate them, on a broader basis elsewhere, similarly structured. This concept of an integrated and concerted mod sequence is applicable to other amps and

preamps and so gave rise to our "mod symphony" sub-title.

Such talk is the obverse of the "they-all-sound-alike" school of thought, but the conditions and assumptions of the contrasted evaluative processes should be appreciated. When one listens for long periods to reproduced music, it is inevitable that differences (non-musical sounds) between reproduced and live music will be noticed. To our thinking, if we can change a piece of audio gear in such a fashion that it repeatedly sounds more like live and less like reproduced music in extended auditioning, the change is then worth doing in principle (cost being another issue).

The POOGE-2 changes are of this type, as were those of the POOGE-1. However, the changes here are recommended with the same qualifiers as previously. They are offered as the opinion of audio hobbyists to the music loving audiophile, no more no less. We offer no iron-clad guarantee of what you'll hear, and no one should be so shortsighted as to believe that even with all the mods that the POOGE-2 is perfect. It is not so—at all—it is audibly better, in a *relative* sense.

We doubt that these modifications will be universally embraced, or immediately understood. We hope those of you who opt to use them, will use all of them, to treat yourself to how good the DH-200 topology can sound. Of course, we realize that only the most dedicated audio experimenters will perform all of the modifications, in light of the relative difficulty, those areas of greater cost considerations, and the nature of subjective perceptions. But, we'd like to report that a number of different persons successfully did all or some of these modifications in parallel during the project (so they are not *that* difficult). And, each of them heard results similar to those reported by Rod Rees (see his comments on p. 00). So, we believe it augurs well for fellow hobbyists that a variety of people across the country, with varying systems, using various types of speakers, in differing rooms, each experienced similar sonic improvements.

## THEORY

### CONTACT CONSIDERATIONS

Much has been written in these pages and elsewhere on the degradation of audio signals by imperfect electrical contacts. Power amplifiers are subject to such problems at a number of non-soldered (or non-welded) contact interfaces; input and output jacks, fuseholders, transistor sockets, and capacitor terminals. Thus some generalized contact related discussion will be useful, as a non-optimum contact at a critical point can undo a great deal of hard work elsewhere.

Electrical contacts can be described as the combination of a linear (ohmic) component and a non-linear (distorting) component!<sup>3,34</sup>

In general we desire low contact resistance for a connection; when this is present both components are reduced.

The non-linear component of contact resistance is termed *constriction resistance*!<sup>3,34</sup> which is appropriate to audio since when it is present this is what it does to the sound! The term constriction resistance describes a condition where the contact's total surface area is not effective in passing current, but the current is actually confined to the area's highest points, or "asperities" ("a-spots," in short form). Thus the current is constricted to a much smaller effective conduction area. This non-linearity is measurable!<sup>34</sup>

High contact pressure, tends to flatten the asperities to larger areas and generally lowers contact resistance and increases conduction efficiency, given adequately clean and flat surfaces!<sup>37</sup> With sufficiently maintained pressure, the contact resistance will also remain stable and low with time. This is the basic theory behind modern crimping hardware, which actually cold-welds metals of the lug and wire strands into a voidless mass.

Examples of relatively low pressure contacts in audio hardware would be phono jacks, and the popular snap-in panel fuseholder. We can solve the latter problem with soldered pigtail fuses, or brass snap-in (one piece) clips. The best phono jacks currently available are non-porous gold plated brass; gold plated magnetic types are undesirable (see section on permeability).

A particularly acute power amplifier problem is the aluminum oxide which forms on the terminals of computer-grade electrolytic capacitors. To counteract this, solder lugs would be preferable electrical contacts, but are simply not always an available option. So, alternative means must be sought to increase the integrity of contact, and enhance reliability in the aluminum-to-copper interface. One solution to this pervasive problem is to use *Indium* as an interfacing metal!<sup>21,33,48</sup>

Indium is a relatively rare metal, with some unique properties desirable for audio connections. It is soft and workable, and is also non-magnetic. The softness and ductility of indium permit it to be cold-welded to interfaced metals, such as copper and aluminum, given sufficiently high force of contact. Under such conditions, mechanical disturbance of the oxidized aluminum surface disrupts the poorly conducting oxide layer, exposing the bare aluminum beneath. Indium then adheres directly to the aluminum, creating a low and stable contact resistance and a connection which is gas tight. These points and others are more completely discussed in the references!<sup>48,49</sup>

In light of the permeability problems of steel hardware, it appears that indium plated non-magnetic screws, lugs, etc. of copper or brass base metal construction are an optimum solution to reliable Al/Cu contacts. These should be securely torqued to specification!<sup>33</sup> A source for indium plated hardware is listed at the end of the article.

In general the hardware available for transistor socketing is not optimum in terms of

either the metals used, or contact pressure applied. Wherever possible (meaning safely and reliably) power transistors would be best soldered at the three interfaces. This of course raises serious problems in terms of metal compatibilities, possible transients, ease of repair, and corrosive fluxes. We cannot say that we presently have solved all of these problems, but we can report that the tin coated Hitachi FETs do solder rather easily, with ordinary 60/40, Sn/Sb alloys. Still, we hesitate to recommend it generally, unless you are individually prepared to risk an accident. A set of matched (required) FETs for a channel is expensive, so be forewarned.

The extensive literature available on contacts<sup>13,34-45</sup> generally supports the use of gold, where freedom of corrosion is important, the forces are low, and the contacts are not of a wiping variety. Wiping contacts, such as switch points, can be designed for a scrubbing action with their actuation. This breaks through the sulfides of silver, for example, allowing very low and reliable contact resistances, and thus low constriction resistance and minimum non-linearity. Lubrication of both gold and silver is recommended.<sup>13</sup>

Any contact surfaces which are subject to relative movement, even of very small excursion, will be subject to *fretting corrosion*. This condition is an accelerated form of atmospheric oxidation at the interface, and is worst in non-noble metals.<sup>43</sup> The result of this corrosion is an increase in contact resistance, by orders of magnitude. Examples of such interfaces are obviously switches, but also include jacks, PC connectors etc. Vibration effects may even be a source of the relative motion, at seemingly innocuous points.

Fretting corrosion is controlled by lubrication, which both lowers and stabilizes the contact resistances.<sup>43,44,45</sup> These studies would tend to predict positive results using such lubricants in audio circuits, for example, Cramolin?

Control of the contact and metal-to-metal interfaces in audio circuits is one of the most important and difficult problems, and will most likely continue to be. This is due both to the lack of widespread appreciation, and the fact that such interfaces can be present even at the component level: for example, in poor end cap terminations on resistors or inserted tab capacitors.

Individual occurrences of contact problems can be extremely subtle and difficult to identify. We can however help the situation immensely by not ignoring the obvious, and using good quality (soldered, or clean, lubricated and tight) contacts on speaker wires both inside and outside the amp and speakers.

## WIRING IMPROVEMENTS

When interconnecting wires are needed in high performance audio circuits, meaning power supply and ground as well as signal wires (both within and outside equipment), we must take a number of considerations into account. Quite often we select wires for a

simple criterion of DC current capability, or such AC considerations as capacitance, but seldom do we pursue the process beyond ordinary factors. This section will show that an examination of the fundamentals of AC signal behavior within wires reveals additional criteria which are also relevant to our choices.

With signal circuits, stray (shunt) capacitance can influence circuit behavior. With high Z conditions, capacitance needs minimization, which suggests low dielectric constant, high quality insulations? Even in the case of medium impedances, dielectrics should be of a high quality low loss type, and further, these qualities ought to be consistent with changes in frequency. In low Z circuits capacitance quality can still be significant, but series inductance may have greater influence on performance, particularly as it may depart from ideal behavior.

Generally, signal paths with low L and C are better. By contrast, low L and high C are desirable for ground returns, and for supply distribution wiring.<sup>12,32</sup> Thus, it is profitable to examine some basic inductor behavior to supplement our knowledge of capacitor behavior.<sup>2,3</sup>

Wires inherently have inductance, even in straight form. For a straight copper wire at 20°C in free space, the inductance (L) in microhenries will be:<sup>10,23</sup>

$$L = 0.0051 \left[ \ln \left( 4 \frac{l}{d} - 0.75 \right) \right]$$

where l and d are the wire's length and diameter, in inches. Interestingly enough, a wire's diameter (and thus gauge) has little influence on inductance. To illustrate, for two one inch lengths of wire of #24 and #10 gauges, the #10 wire has an inductance of 0.018μH, less than #24's 0.026μH. However, the ratio of their cross sectional area is 25/1, a far greater figure than the less than one half the inductance ratio.

This makes the point in general that increasing wire diameter does relatively little to lower inductance, but does lower DC resistance, proportionally. The DC resistance (R) of a copper wire at 20°C in ohms is:<sup>29</sup>

$$R = \frac{\rho l}{A}$$

ρ = volume resistivity of copper in ohm • meters;

= 1.7241 × 10<sup>-8</sup> ohm • meter.

l = length in meters

A = cross sectional area in meters<sup>2</sup>

For the two wires above, the #10 wire has a DC resistance of 0.08 milliohm, while that of the #24 is 2 milliohms (which is in the ratio of their areas).

A clearer picture of the disproportionate behavior of the two wire sizes may be seen by observing their DC and AC operation and considering their inductive reactance at a (common) high frequency. For example, one inch of a #18 power supply wire has an inductance of 0.023μH, while a foot of it will be 0.43μH.

Inductive reactance, X<sub>L</sub> in ohms is:

$$X_L = 2\pi fL$$

where f is in hertz, and L in henries.

At 20kHz the one inch wire has a reactance of 3 milliohms, but the one foot wire has a reactance of 50 milliohms. Of course one inch wires for power supplies are not generally practical and in most cases lengths of a foot or more are necessary. The one foot wire will, by virtue of its increasing impedance at high frequency, effect a decoupling of the load from the power supply due to its impedance at high frequency, (in addition to the DC resistance effects). A low power supply source impedance (on the order of 10 milliohms) is very beneficial to amplifier circuitry<sup>5,6,7,12,32</sup>; but unless care is taken it can easily be negated by even the optimum distribution methods (less than is in fact achieved at the supply terminals themselves).

## SKIN EFFECT

When DC (or very low frequency AC) currents flow along a conductor, the current density is uniformly distributed throughout the cross section. Due to field effects, however, at high frequencies the current density shifts towards the surface, becoming less and less concentrated at the center. This phenomenon is known as the *skin effect*, and the area from the surface inward carrying the AC current is known as the *skin depth*. One way to picture this effect is to imagine the AC conductor is a hollow conductive tube with the tube's wall thickness representing skin depth.

Skin depth is defined as that depth below the surface at which the current density has decreased to 1/e of the value at the surface. Skin depth is generally symbolized as δ, and may also be described as *reference depth*.<sup>11</sup>

Skin depth is an important parameter to an understanding of AC and audio signal behavior, as can be appreciated from the terms which mathematically describe it.<sup>23</sup> The generalized form of the equation for skin depth in meters is:

$$\delta = 503 \sqrt{\frac{\rho}{\mu_r f}} \text{ meters}$$

where ρ is the resistivity of the conductor in ohm•meters, μ<sub>r</sub> is the permeability of the conductor, relative to a vacuum and f is the frequency in Hz.

As we see from this expression, frequency as well as resistivity and relative permeability influence skin depth, the latter two being under our control. For most conductors (copper, silver) relative permeability is very close to unity, but ferromagnetic conductors (iron, nickel, etc) can exhibit permeabilities in excess of a hundred or more, with resulting reduction of skin depth to a smaller proportion, relative to the low permeability conductor materials. Common low resistivity, unity-permeability conductors such as copper and silver have only minor differing effects on skin depth, since they have order-of-magni-

tude grouped resistivities. Close behind these two in conductivity among low permeability types comes gold and aluminum.

For use with copper conductors, the equation for skin depth can be simplified to (with  $f$  still in Hertz,  $\delta$  in meters):

$$\delta = \frac{0.066}{\sqrt{f}} \text{ meters}$$

Alternatively, to express skin depth in inches, the general form is<sup>11</sup>

$$\delta = 3160 \sqrt{\frac{\rho}{\mu_r f}} \text{ inches}$$

where  $\rho = 0.68 \times 10^{-6} \text{ ohm} \cdot \text{inch}$  or, for copper conductors,

$$\delta = \frac{2.60}{\sqrt{f}} \text{ inches}$$

Happily, any of the above expressions can also be used with silver plated conductors with little error, as silver has a lower (but close) resistivity than copper. Further, the typical plating depth on the order of 50  $\mu$ -inches will be a relatively low percentage of the skin depth.

Plugging real world numbers into this expression enables a good feel for its implications regarding AC conduction. A #18 conductor has an 0.0403 inch diameter, and its skin depth at 20kHz will be approximately 0.020 inches (or 0.5mm). Thus, for this conductor diameter the skin depth extends approximately to the center, *which is a highly desirable situation*. We can generalize this concept with a mathematical statement, showing the desired relation of conductor diameter ( $d$ ) and skin depth ( $\delta$ ) for the highest frequency of interest:

$$d \leq 2\delta$$

Note that were the conductor a #00 (0.364 inch diameter), the skin depth would still be the same, *but it would penetrate only about 1/10 the conductor radius*. Obviously the much larger cross sectional area is utilized much less effectively for AC, than for DC. The term which describes the effective resistance of the conductor at high frequencies (conduction in the skin depth area only) is called  $R_{AC}$ , and is expressed as:

$$R_{AC} = \frac{\rho l}{\pi \delta (d - \delta)}$$

The parameter which relates the conductor's resistance as determined by skin depth to the DC resistance is known simply as  $R_{AC}/R_{DC}$ , the ratio of the two resistances. Given the skin depth at a frequency ( $f$ ), and the diameter of the wire ( $d$ ) this is:

$$\frac{R_{AC}}{R_{DC}} = \frac{d^2}{4\delta(d - \delta)}$$

where  $d$  and  $\delta$  are in meters (note this relation is based on an assumed AC conduction in the skin depth area only. It is also only meaningful for  $d > \delta$ ).

For the two wire examples just mentioned, the #00 wire has an  $R_{AC}/R_{DC}$  of 5.2; while for the #18 wire this ratio is 1.008, very close to unity. These ratios indicate the relative effectiveness of a given conductor at a given frequency, compared to its DC capability. They are not a direct indicator of AC conducting capability, *on an absolute scale*.

If we were to optimize the conductor size on the basis of 100kHz instead of 20kHz, the skin depth then becomes 0.008" (0.2mm), and the conductor size for  $d \approx 2\delta$  is close to #26 ( $R_{AC}/R_{DC} = 1.001$ ). Note that for this frequency and a #18 conductor example,  $R_{AC}/R_{DC}$  becomes 1.54, whereas for 20kHz it was near optimum.

These points are being made to illustrate the concept that as the total bandwidth of signal transmission is increased, the more effective (round) wire size, in terms of signal transmission uniformity, *becomes smaller*. This is not at all to say that the singular simple substitution of smaller wires is to be preferred, as this is only part of the solution, which will be discussed momentarily.

Before departing this consideration of the individual wire, it is interesting to consider how the transformation from a solid round conductor to a conducting shell might influence audio signals. Since such a process effectively *does* take place in a conductor with shallow skin depth, as we move from low to high frequencies, this suggests a possible change of phase relationships between fundamental/harmonic components. This, in fact, is what does happen, as the phase lag at the frequency  $f$ , referred to the surface, is one radian (57.3 degrees) at one skin depth inward. Thus, considering an audio signal's broad band of signal spectrum, phase degradation will take place when the skin depth is not an appreciably large percentage of the conductor, resulting in a loss of coherence.

## LITZ WIRING

For both high DC and AC current carrying capability (low DC and AC resistance) in audio wires, multiple small wires can be *paralleled*, with each of the individual wires a single unit selected for optimum skin depth. DC requirements can be met simply by satisfying a total cross sectional area criteria, so as to meet the required DC resistance. This technique allows the best of both worlds to be realized, but at the expense of tedium and a larger overall wiring bundle (unless very low thickness insulations are used). Note that this technique requires that all individual strands along their length be insulated, with common terminations at either end.

This is by no means a new technique of low-loss AC wiring, and the German word Litzendraht refers to the inter-weaving of a number of small strands, and is shortened to simply "Litz" wire. Litz wires (in bulk form) are commercially available in equivalents of virtually any size, being composed of as many as a thousand or more small individual wires on the order of #36 to #44 (see sources

at the end of article, and geometric configurations described in references 22 and 47).

The Litz concept as applied to audio was pioneered by J. Hiraga in 1977<sup>8</sup> and has been introduced to this country in the form of speaker and interconnecting leads. To our knowledge, no documented usage related to audio gear as yet exists. We believe these principles are just as applicable here as elsewhere.

Effective application of the Litz concept must be tempered by practicality to some degree, when all relevant factors are considered. For example, one can optimize bandwidth transmission by increasingly fine wires, but then one might need several hundred of them to wire up each power lead in a high power amp. Also, the true Litzendraht configuration braids all the wires in an interleaved pattern, such that each individual wire passes through the center, thus equalizing the fields. (See the bibliography, reference 27 written in 1915; and the bib. therein.)

Obviously, braiding is a difficult task for the amateur, albeit not an impossible one. Fortunately, it appears that good advantage of the Litz principle to optimize conductor bandwidth and efficiency can be had, by simply paralleling and bundling a relatively low number (20 or less) of medium size conductors, which are individually on the order of 24 to 30 gauge. Table 1 shows how these wire gauges can be paralleled to yield larger equivalent gauges, up to #11. For a given conductor, the wires are cut to length and stripped at the ends (as shown in Detail D, method b), and the bundle secured with tubing, spiral wrap, or wire ties. To keep inductance low, power supply wires bundles and their returns are tightly bundled together where possible, and/or secured against the chassis. Signal wire bundles are twisted, where possible. Low level points are shielded, with an overall conductor grounded at one end only.<sup>10</sup> Signal pairs consist of identical conductors for each side.

In terms of the individual wires to be used to compose these parallel sets, a number of further criteria need to be stated. Each individual wire should be a *solid* configuration with maximum conductor purity, and high quality insulation. J. Hiraga<sup>8</sup> reports polyurethane insulation as superior, likely due to its low dissipation factor compared to most other magnet wire insulations commonly available (see reference 22, table 18, p. 7-26. We do not know whether his studies encompassed low dielectric constant film insulations.) Our experience has shown wire insulation quality relevant to audio to follow patterns similar to capacitors<sup>2,3</sup> with the low dissipation factor, lower dielectric constant materials superior.

Two of the wire's most important characteristics are the conductor and its coating. Oxidation and/or corrosion effects at near or below the surface are most undesirable, since this area is where high frequency energy is concentrated. (This extends inward of

course, for  $d \approx 2\delta$ ). Thus, materials which show high conductivity and minimum corrosion (and thus, minimum non-linearity) should be used, such as oxygen free high conductivity copper (OFHC). The overall conductor, and plating if present should then be protected with a high quality insulation, preferably one as gas free as possible. This will exclude the atmosphere and minimize oxidation susceptibility. The OFHC copper is a process which is designed to preclude internal embrittlement and subsequent cracking, due to hydrogen.<sup>21</sup>

Stranded wires of a similar composition are available, but are not desirable, as they do not allow a true Litz operation. Further, they allow inter-strand rectification effects to develop, due to constriction resistance and imperfect ohmic contacts. This is most likely to occur at the surface where the high frequency energy is greatest and corrosion is more likely to occur.

**TABLE I**

*Wire size equivalents for  
paralleled solid wire combinations.  
Equivalent gauge using combinations  
shown (approx.)*

| # of<br>cond.<br>paralleled (404cm) | #24<br>(254.1cm) | #26<br>(159.8cm) | #28<br>(100.5cm) | #30 |
|-------------------------------------|------------------|------------------|------------------|-----|
| 1                                   | 24               | 26               | 28               | 30  |
| 2                                   | 21               | 23               | 25               | 27  |
| 3                                   | 19               | 21               | 23               | 25  |
| 4                                   | 18               | 20               | 22               | 24  |
| 5                                   | 17               | 19               | 21               | 23  |
| 6                                   | 16               | 18               | 20               | 22  |
| 7                                   |                  |                  |                  |     |
| 8                                   | 15               | 17               | 19               | 21  |
| 9                                   |                  |                  |                  |     |
| 10                                  | 14               | 16               | 18               | 20  |
| 11                                  |                  |                  |                  |     |
| 12                                  |                  |                  |                  |     |
| 13                                  | 13               | 15               | 17               | 19  |
| 14                                  |                  |                  |                  |     |
| 15                                  |                  |                  |                  |     |
| 16                                  | 12               | 14               | 16               | 18  |
| 17                                  |                  |                  |                  |     |
| 18                                  |                  |                  |                  |     |
| 19                                  |                  |                  |                  |     |
| 20                                  | 11               | 13               | 15               | 17  |

For the amateur experimenter, the above criteria might seem impossibly narrow and impractical. Fortunately for us however, the computer industry has developed a low cost wire type for wire wrapping<sup>22,23,31</sup> which meets most if not all of these criteria. Wire wrap is available in gauges of 22 to 30 from a wide variety of suppliers in bulk rolls, or in pre-cut/pre-stripped lengths. This wire is OFHC copper, with a silver plating, and the insulation most commonly used is Kynar (UL style 1422, 1423). Also generally used is Tefzel insulation (UL style 1516, 1523).

While the dielectric constant of Kynar is relatively high (6.4), Tefzel is desirably low (2.6) bettered only by Teflon, which is unfor-

tunately scarce. The determining use factor for the amateur is most likely to be availability, better insulating materials being so much more difficult to obtain. (A number of wire wrap wire sources are listed at the end of the article.) And, it can certainly be said that even the Kynar wire type will be far superior to conventional non-Litz types, or types with inter-strand rectification, and/or conductor impurities.

In some cases it may not be practical to use multiple parallel wires, such as for 2-3 inch, or other small lengths. A least-compromise alternative for such cases is a solid buss of OFHC copper, preferably silver plated, with a snug sleeve of quality insulation. This is shown in *Detail D, method a*.

## OTHER APPLICATIONS OF MULTIPLE PARALLEL WIRES

The above discussion summarizes the "practical reality" approach to rewiring, as applicable to inside amps and preamps. We do not mean to imply that a limit to the number of strands or smallest useful conductor size is being established in concrete terms, and we encourage readers to experiment further with these ideas, using the conductor types mentioned. We suggest that if Litz-type wiring works in one place, it is likely also to benefit the entire chain to the speaker, and *within* the speaker's cabinet also. It seems most likely to benefit at points of high frequencies pre-emphasis, such as for example prior to a RIAA equalization.

For those not yet acquainted with the idea, two simple and inexpensive trial experiments might be to fabricate interconnect and speaker leads. For the interconnects we suggest eight strands of #24 or 26 (8P24) wire wrap wire, per conductor, per side of a stereo pair (32 conductors in all). Use high quality phono plugs (a gold plated brass construction is suggested), and shield each pair with an overall braid, grounded at one end only.<sup>30</sup> For speaker leads, try 16P24 per conductor (64 conductors in all), and bundle with sleeving or spiral wrap, tying the sides of the pair together along their length. This yields a #12 gauge equivalent wire. Solder at the speaker end if possible, and use lengths no longer than necessary. These experiments should give you a frame of reference for what this wire concept can do on a simple basis; with this knowledge you will be able to gain the confidence for internal rewiring projects. Commercially available cables using advanced Litz concepts and materials are mentioned at the end of the article.

## GENERAL CONDUCTOR PERMEABILITY CONSIDERATIONS

In addition to the skin effect related wiring improvement concepts outlined above, some more generalized comments can be applied to all audio conductors, which includes terminals, connectors, switches, component leads and bodies, etc. These considerations are basically ones related to the materials and

composition of the base metal conductors used, *in terms of permeability*.

It has been reported that ferromagnetic metals (iron, etc) measurably increase distortion, when in close proximity to signal carrying wires and components.<sup>19</sup> Independently, measurements of harmonic distortion in ferromagnetic conductors have been observed by Brian Elliot.<sup>20</sup> To paraphrase from Yamada,<sup>19</sup> the factors characterizing the behavior of this distortion are high current levels, presence of magnetic materials 50mm (2") or less distant from signal leads, operation at frequencies of 1kHz or more, and the predomination of odd order terms within the distortion products.

The greater permeability, magnetic non-linearity and hysteresis of ferromagnetic materials is responsible for this distortion (permeability is one or unity for paramagnetic materials). This characteristic is quite a basic one, and descriptive analysis can be found in virtually any text treating electromagnetics.<sup>23,26</sup> The curve of magnetic flux density (B) plotted against the magnetizing force (H) gives us the familiar hysteresis loop of ferromagnetic materials.

We believe the important factors here are not to re-establish long-known non-linear parameters, but rather to relate how they might affect audio signals, and what audiophiles can do to counteract the undesirable behavior, such as distortion.

If we can accept the conclusions of Yamada<sup>19</sup> restated above, as based on objective tests, then it follows that signal conductors which are also ferro-magnetic, (iron, steel, nickel, copperweld) will also show similar (if not greater) distortion behavior. Certainly there can be no tighter coupling to a signal carrying wire than to make the wire *itself* magnetic, and the distortion generated then approaches unity coupling to the signal. These authors have noticed that there can be audible distortion when audio currents pass thru ferromagnetic conductors, and this seems to be especially true where high current and/or high frequency levels are present. For example, WJ first noticed this when changing connections to a magnetic-lead polypropylene capacitor in the crossover of his Magnepan MG-11A's. Subsequent substitution of all copper lead polypropylene caps removed the "hotness" and "hash" observed, as did similar later upgrades to other components elsewhere. In general, it appears that the "magnetic lead" component problem is one over which little or no manufacturer control is exercised, and many do not even indicate by specification what materials are used in their leads and/or case materials. For such situations the potential user can test the unmounted component easily with a small magnet, to see if it is attracted, or simply inquire as to the specifics of manufactured materials.

We do not mean to overstate the case against magnetic conductor components, for certainly exactly how the component is employed within the circuit should influence the degree of potential audibility. However, if

we have a choice between two otherwise similar components, the non-magnetic type would seem to be the more attractive, without penalty.

The authors note here that some of the specific capacitor types suggested in our previous articles<sup>2</sup> for audio applications *do* employ magnetic conducting materials in their construction, and so warn the reader (low permeability leads/construction was not a topic of that discussion). Recent discussions suggesting specific component types controlled in this regard should also be helpful.<sup>12</sup>

In a general context relating to the behavior patterns of non-ideal components, it is interesting to note both inductance and capacitance can be described by a hysteresis curve when their permeability and dielectric constant, respectively, are significantly greater than unity.<sup>23</sup> The non-linear manifestations related to audio are of an in-

verse nature, as are capacitance and inductance themselves. For example, the non-linear impedance due to ferromagnetic materials is most noticeable in series with the signal path; signal wires/cables, power supply wiring grounds, connectors. By contrast, dielectric problems are most noticeable when in shunt with the signal; such as when used in filters, equalization, error correction paths. To make an application analogy, minimizing inductance and using non-ferrous conducting materials seems, from our experiences, to provide improvements similar to those experienced with capacitors of upgraded dielectrics. It should be clear at this point that high permeability conductors have two inherent strikes against their use for audio; the degradation of skin depth, and the non-linear behavior.

However, in the final analysis, we should point out that the exact significance of

permeability, low inductance, and low dielectric constants depends ultimately upon the actual circuit function; that is, the parameters, impedance and interaction within the circuit, and upon the complete system.

A system completely free of these non-linear materials and distortions from source to loudspeaker can be more revealing of a (single) added (or changed) non-linear part, than is a system full of non-ideal, non-linear parts and removing/replacing one of them. With regard to the mod portion of this article, if you execute all the steps described, you will have exorcised all such above problems that could be controlled (plus others), and we think you'll hear more from within the signal presented to the POOGE-2 or other conceptually similar such mod. (In many senses this was also true of Amer!) □

## POOGE-2: A Description of the Sonic Changes

by ROD REES\*

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When Walt Jung asked me to describe the differences I heard while converting a Hafler DH-200 into a POOGE-2, I decided to first deal with a couple of procedural problems reviewers face. I hope a few initial paragraphs spent on this task will enhance the reader's appreciation of this description of the sonic changes.

**THE CAVEATS:** Attempting to describe A/B aural differences in components can lead in two directions: one related to absolute judgments of quality, or, by contrast, comparative statements of performance within a defined context. The quality judgment game is enticing, and continues to be played in some hi-fi reviews. Note the frequency of such statements as "more accurate," "more musical," "proper amount of depth," and "deficient bass response." Of course, we all agree to play this game when comparing state-of-the-art equipment to discount-house specials, but in the upper reaches of "fi" the game loses its utility. Far too many variables interact to allow a cavalier attitude toward absolute quality judgments.

To illustrate this point, consider the cartridge capacitive load issues. Changing the value of a preamp's input loading capacitor can change the sonic character of a cartridge from "dull" to "bright." Is this new sonic character a feature of the preamp or of the cartridge? Of the preamp, you might say, because that is where the new capacitor is physically located. However, the capacitor can just as easily be placed in the cartridge body or headshell, or even in the interconnecting cable. So, if the new sonic character is not a feature of either cartridge or preamp then is it a feature of the capacitor itself? Again, no, because changing to another cartridge might change the sound to its original character.

The key point here is the arbitrary nature of our component categories; convention dictates, although conventions can easily disintegrate. We often try to get around this category/definition problem by using the concept of an "interface," but this quickly becomes an infinite regress (consider the interface between an in-

terface and the components it interfaces with). And of course, when we begin comparing "components" that are internally modified, as with the POOGE-2, the conventional categories become quite silly, and irrelevant.

Even more troublesome to the comparison task is the concept of an interaction, which can be defined as a situation wherein the direction of the effect of changing one variable cannot be predicted without knowledge of the variable with which it interacts (speaker A sounds better than speaker B with amp X, but vice versa with amp Z.) Interactions are difficult to identify as well as to understand; for example, the cartridge loading phenomenon described above is usually called an "interaction between cartridge and preamp" but it probably is not interactive in the sense defined here. The point, however, is that interactions between components do exist, and even if none are known to exist regarding a particular interface they can always arise, given a new version of one of the components. What this means is that we are always on shaky ground in making absolute judgments of quality because of the unpredictability of interactions.

With two such reasons for avoiding absolute quality judgments, what about comparative statements: how are they different? First, such statements will always remain useful in the sense that a difference once identified will always be valid, within the original context. And second, they tend to be more specific: if I can hear the third bassoonist blow her nose only when I use amp X, this is precise enough for anyone to identify. But don't assume that such an amp would necessarily be better; a narrow band-pass filter centered on the resonant frequency of her nasal cavity would highlight this sonic nuance superbly. These two features, precision and faithfulness over time, give the comparative statement its utility.

**The Context:** for producing a usable description of change includes the reproducing chain, the software, the environment, the A/B procedure, and the listener's expectations and skills. As for expectations, I was initially dubious that the simple changes proposed would make much difference, so I expected a gruelling task, straining my powers of perception in order to detect subtle changes. Procedurally, I first re-familiarized myself with the sound of my system for several days. Having divided the series of modifications into several convenient groups, I then, for each group, listened to two or three reference recordings, shut down the system to do the modification (roughly 1-2 hours in each case), and then fired up and listened again to the reference recordings. These were followed by many other familiar recordings over the

*Continued on page 14*



## POOGE 2: SONIC CHANGES

Continued from page 12

next day or two. Of course I always listened with my eyes closed, but I don't think that this is what is meant by "double-blind" procedure.

My listening environment is heavily damped with wall-to-wall carpet, floor-to-ceiling drapes right, left, and front, and a large, irregular open space behind. The speakers are separated by 65", and are angled directly towards one's head, about 48" distant at ear height. The system consists of a home-brew turntable with design for resonance damping; Grace 707 MkII tone arm with outboard viscous damping; Grado Signature 1a, high output Adcom and Dynavector Ruby, all with meticulous alignment; Leach Wideband Preamplifier (FET version) with numerous modifications; and two home-brew loudspeakers tuned for phase coherency and transient response, one a 2-way lacking low bass, the other a 3-way tuned to 32Hz. I have also invested effort in choosing interconnecting cables and in eliminating mechanical contacts. Among my audiophile friends this system is respected primarily for its tight imaging and accurate tonal balance. The reference recordings I used were not chosen for state-of-the-art reputation, but rather because they highlighted some particular sonic feature.

**The Comparisons:** Rather than detail the step-by-step changes I will comment on the total effect, covering the 10 sonic attributes categorized below (see reference recording list for RR numbers).

**A. Greater sense of transient impact.** The various percussive and plucked sounds throughout *ECM* RR-5 are now more evident, and with less sense of overload. On *Nonesuch* RR-8 the impact transients on the timpani, chromatic drums, and bass drum give a clear impression of the drum head being compressed and then released, a key feature of live percussion in my opinion. The transients on *Island* RR-7 are sharper but simultaneously less harsh. Several cases of what I had thought to be cartridge mistracking have disappeared, as have other forms of (presumed) transient overload distortion. The transformer change seems especially important in alleviating these problems.

**B. Richer, more coherent harmonic structure.** On *Desmar* RR-9 the individual finger plucks of the two harps seem to "snap" and then become enveloped in a natural-sounding harmonic structure, which seems to move out from the initial transient locus somewhat like waves from a pebble splash. While these harmonics fill a rather large space they retain a precision of location, and even the spatial direction of the harmonic surges can sometimes be heard.

**C. More body but less weight.** What I mean by this is that coherent harmonics are present that give to a sonic event a character akin to its natural density, as opposed to harmonics which give merely a ponderous or weighty (but unnatural) character. This phenomenon is evident in drums (RR-12), male vocals (RR-4) and gongs (RR-10) and is probably related to the bass changes detailed below.

**D. Greater bass-midrange continuity.** This is another manifestation of coherent harmonic structure. Listen to a live performance of a string bass being bowed down the scale. You will notice that as the fundamental reaches lower and lower the upper harmonics are not diminished; rather, the lower tones are merely added to the rich mid and treble harmonics. The lute on *Accent* RR-6 has a beautiful lower register which prior to the POOGE-2 modifications sounded blunted and distinctly separate from the midrange. Now these lower tones have more "growl and bite" and their harmonic structure seems intact and seamless throughout.

**E. Cleaner bass.** The bass response down to the limits of my 3-way system is more complete, with less sense of effort, and has greater tonal and spatial differentiation. These changes are quite evident on almost any recording.

**F. Greater definition at stage extremities.** Sounds at the extreme right, left, and rear of the sonic stage that were previously blunted or softened became clearer with more precise positions in space. This is especially true of *Vanguard* RR-1 (side 1, band 4): listen for greater clarity and hall ambience in the sing-along au-

dience on the left, and notice when Pete Seeger steps back from the mike on the right. The spatial "edges" in recordings with exaggerated laterality also became sharper (e.g., *RR-3*). On *Turnabout* RR-11 it seems as though I am sitting in the bleachers with the orchestra spread out before me single file across the entire length of a soccer pitch. And on *Nonesuch* RR-8 the drum recorded at low volume at the extreme rear of the stage has greater clarity and definition than before.

**G. Greater sense of 3-dimensional space.** On naturally miked recordings such as *Peters* RR-13 the perception of an open space, a sonic environment if you please, that is laid over the listening room is striking. The space is there even when the lute is quiet (but don't forget to listen for those birds twittering in the background). Also notice on side 2 of this recording that the mikes were moved closer to the lute at least twice, losing, of course, that glorious open space. Incidental sounds from the rear of the recording stage in *ECM* RR-16 appear in a subtle but vividly open space.

**H. More openness of dense multitracking.** *Chrysalis* RR-14 (British pressing) previously had a strong tendency to sound "murky" due to the dense multitracking, but emerged after the POOGE-2 modifications with a rich and detailed texture, an unexpected clarity. This same phenomenon has occurred with several older pop/rock recordings, as well as with heavily orchestrated symphonies recorded with strong ambience.

**I. Phase relations are more evident.** Side 2 of *Reprise* RR-15 has several cuts with striking phase anomalies in the mixdown (intentional, no doubt). The effect through the POOGE-2 is akin to listening over headphones, wherein voices and instruments clearly emerge from "impossible" spaces with "impossible" bodies.

**J. Dynamic range is expanded both up and down.** The increased dynamics of loud sounds is obvious, but more interesting is the downward expansion of quiet sounds. On auditioning *Columbia* RR-12, at one point the overall SPL suddenly started decreasing. I thought, "Oh no! Something blew and I'm hearing my power-supply capacitors bleeding down." Just as I was about to get up to see that was the matter, I realized the engineer had simply turned the master level control slowly down in anticipation of a "dramatic" increase in volume later on. Also, on almost all recordings numerous quiet sounds now emerge that were not evident before.

The transformer change produces a striking increase in dynamics. I find that (now) I set the VOL control higher than before, but even so the low amplitude sounds are perceptually quieter and more delicate, while the high amplitude transients appear with startling suddenness, and then are gone equally quickly (e.g., *EMI* RR-17).

**The Conclusions:** Non-subtle changes were evident in every sonic aspect that I chose to listen for, but most especially in transient response and dynamic range, harmonic and reverberant patterns, bass response and definition, and delicacy and vividness of low level detail. I would characterize the overall changes in two ways; information and impact. There are more "things" coming through the system, and each thing stands out in its own audibly coherent spatial and tonal milieu. But even while standing out they are also more integrated through delicate harmonic and ambient patterns. A friend who was familiar with my system listened to it again, after some of the POOGE-2 modifications. His first comment was that the amount of sonic information was overwhelming. His second comment was that when a system sounds this tight its failure to meet reality is even more painfully evident. I agree.

Finally, a word about construction: there are no particularly difficult steps, although reasonable dexterity and soldering skills are required. Anyone who built his DH-200 from a kit, or who has wired other electronic kits should have no trouble. Others should carefully study the DH-200 construction manual and these instructions before beginning. Preparing the multiple-ply wire lengths beforehand can be a help. Overall, I think most DH-200

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owners will find their effort well rewarded, but the more dedicated audiophiles will find that the amplifier has become unforgiving in its exposure of flaws elsewhere in the audio chain. It was often the case that what I had thought to be careful attention to details (such as cartridge alignment and speaker placement) were shown to be inadequate by the much greater resolving power of the modified amp. In effect, my tolerance in both senses of the word have changed dramatically.

### REFERENCE RECORDINGS (RR)

- |   |                   |
|---|-------------------|
| 1. The Weavers Reunion at Carnegie Hall-1963              | Vanguard VSD-2150 |
| 2. Los Romero: Telemann, Bach, Scarlatti, Elliot, Dowland | Philips 9500 536  |

- |  |                       |
|--|-----------------------|
| 3. Stravinsky: The Firebird (Complete)                 | Col M-33508           |
| 4. Taj Mahal: Oooh so good'n blues                     | Col KC-32600          |
| 5. Gismonti: Danca das cabecas                         | ECM 1089              |
| 6. Junghanel: German lute music of the 18th century    | Accent ACC-7801       |
| 7. The Chieftains: Bonaparte's Retreat                 | Island ILPS-9432      |
| 8. Percussion Music                                    | Nonesuch H-71291      |
| 9. Johnson and Kozikova: Music for two Harps           | Desmar DSM-1018-G     |
| 10. Javanese court gamelan, Vol. III                   | Nonesuch H-72083      |
| 11. Holst: The Planets                                 | Turnabout QTV-S-34598 |
| 12. Olatunji! Drums of passion                         | Col CS-8210           |
| 13. Bailes: Music for Lute                             | Peters Int'l PLE-052  |
| 14. Jethro Tull: A passion play                        | Chrysalis CHR-1040    |
| 15. The Beach Boys: Surf's up                          | Reprise RS-6453       |
| 16. Art Ensemble of Chicago: Nice Guys                 | ECM 1-1126            |
| 17. Bartok: Music for Strings, Percussion, and Celesta | EMI ASD-3655          |

## THE MOD SEQUENCE

Figure 1A is the schematic of one channel of the POOGE-2 amplifier, with parts identified as to value and type. Figure 1B shows the power supply with revisions and plug-in filter bank option, similar to WJ's article in *Audio*.<sup>22</sup> Step 12 of the instructions should be your guide to applying the power options; Fig. 1B actually shows only the minimum recommended.

Some comments may be helpful about the history of the DH-200, and its in-line factory changes. Recent production units use film or mica for small value caps, and the transistor types designated in Fig. 1A. A change employed in the recent DH-500 alters the value of  $R_8/R_{10}$  and  $R_{15}/R_{16}$  to  $47\Omega$ , and  $C_9$  to  $330\text{pF}$ . This is an option for DH-200 owners, if executed, these authors suggest  $49.9\Omega$  metal films for the resistors, and a polystyrene for  $C_9$ .

The following step-by-step changes detail the series of mods which make up the POOGE-2 and are inter-related to some extent, thus the listed order. The mods are not problematic in a hazard sense (to you or the amp), but they are not recommended for the first time builder, either. As always, be careful of polarities, work with the amp unplugged, and  $C_{16}/C_{17}$  discharged, and take reasonable care. For those who want to "skip around" and do selective mods, we strongly suggest you read the entire sequence carefully before doing so, and we do not recommend a random mod. You execute these changes at your own risk, and with the understanding that it will invalidate your warranty. [Hafler Co. will not answer any queries about these mods or their results.—ED.] We apologize for the somewhat "hand-holding" nature of the steps, but believe it necessary to properly tie down the physical differences and wiring details.

Obviously these mods are much easier to do on a *kit* DH-200, since much less must be undone. However, the sequence as written assumes the amp is completed, since this will be true in many cases.

### 1. Replace Speaker Binding Posts with 30A Gold Plated Types

Use the H. H. Smith #257 or Superior single posts, in four places (two red, two black). Or you may use two equivalent quality dual posts.

The mounting holes must be redrilled (or punched) to  $\frac{1}{2}$ ", to accept the larger body. Do this very carefully, to avoid damage to other parts. We suggest that you do this step before all others if it is to be done, or at the very least, remove  $C_{16}$  and  $C_{17}$  temporarily. Shake out any metal bits and pieces from the chassis interior when drilling is complete (or use a small magnet to attract them). Be careful to insure



Photo 1: Closeup of input jack wiring and C1.

no burrs on the four chassis holes, then install the new binding posts.

You need not wire the posts immediately, as you will be replacing the speaker wires in a following step. With a toothpick, apply a dab of Cramolin to each new post.

### 2. Replace Input RCA Jacks With Gold Plated Types

Use two of the Old Colony large gold plated (brass base) jack, which mounts with the nut on the outside of the chassis. No re-drilling is required after removal of the original jacks, and a nylon shoulder and flat washer are used with the new assembly.

Prior to mounting the jacks, prewire the ground lug on each, using a 3" length of ICB16 buss. The jack and its lug are then mounted, and the free ends of the wire are connected in the next step. See *Detail A* for reference.

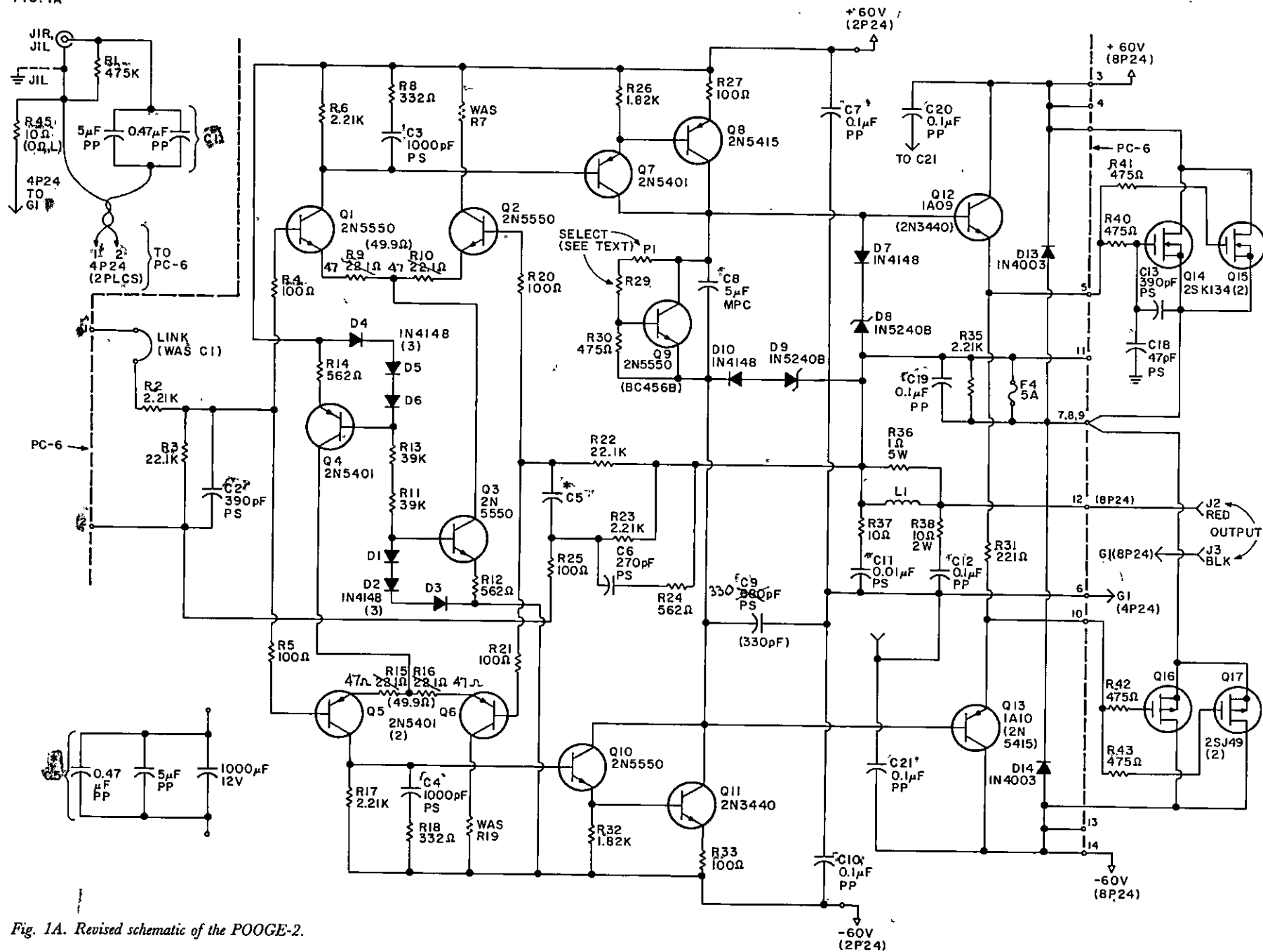
With a toothpick, apply a dab of Cramolin to the jack inner contact and outer surface. (Even if you retain the original RCA tin plated jacks this is still recommended).

### 3. C1 Replacement

This step replaces the original board mounted non-polar electrolytic with an off card film capacitor. Because of the larger physical size, the

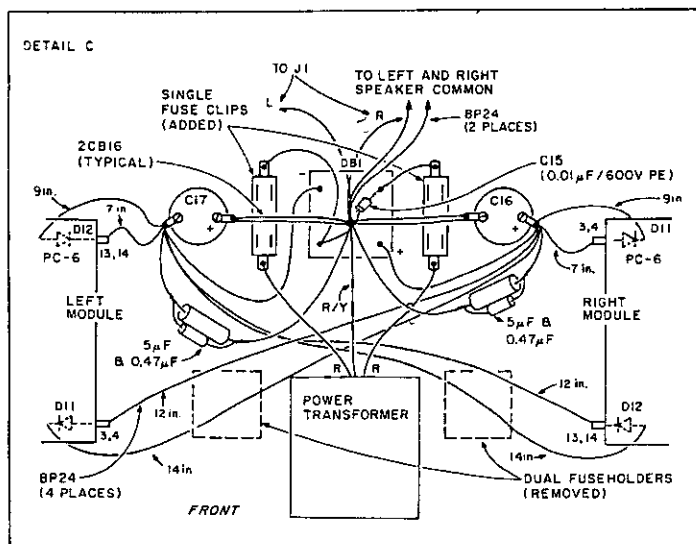
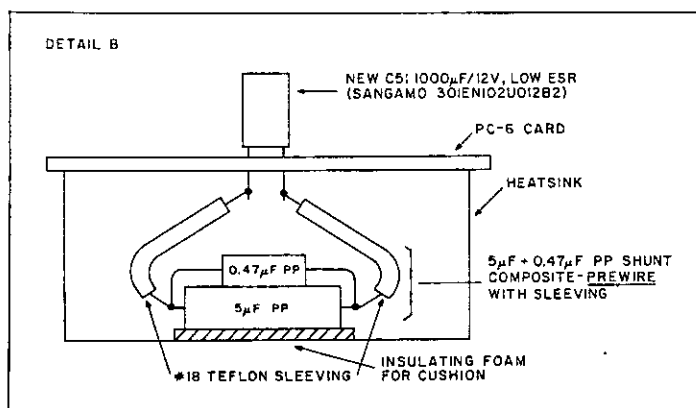
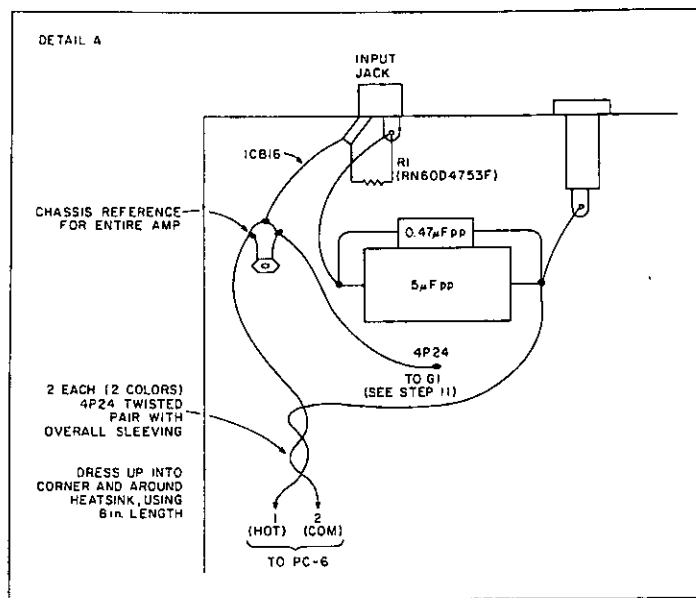


FIG. 1A



*Fig. 1A. Revised schematic of the POOGE-2.*

Remove the original  $C_1$  ( $10\mu\text{F}$  electrolytic) from each PC-6 circuit card, and replace it with a 1SCB24 wire. At a location near each input jack you will note there is a mounting screw for the two feet. At the LEFT input, install a ground lug under this screw, as noted in *Detail A*. Between the center pin of the input jack and the center pin of the fuseholder mount a  $5\mu\text{F}$ , 100V PP capacitor, which has been prewired with a  $0.47\mu\text{F}$  PP shunt. Use #18 sleeving on the leads, dressing the shunt combination up against the inner side of the



At the LEFT input end, connect a 1CB16 lead from the common terminal of input jack to the ground lug as shown, after first slipping sleeving over the bare wire. Trim the final lengths to no longer than necessary. R<sub>1</sub> is connected between the terminals of the input jack. Using dual 4P24 twisted pair of wires of contrasting colors trim an 8" (twisted) length, and wire one color to the LEFT ground lug which is the common ground reference for the amp; the opposite end of this wire goes to PC-6 eyelet 2. The second 4P24 wire goes to the fuse holder end of C<sub>1</sub>; and to PC-6 eyelet 1 at the module end. Dress this twisted pair up into the corner, as noted, using an overall jacket of sleeving. A 4P24 wire will also be connected to G1 from the ground lug, in step 11. See photo #2.

Some comment is appropriate for user situations which do not necessarily demand full broad band performance of  $C_1$ . The value of  $C_1$  specified results in a  $C_1 - (R_2 + R_3)$  corner of 1.2Hz; for lower frequencies  $C_1$  can be increased. For cases where the POOGE-2 is to be used as a mid-range or tweeter amp,  $C_1$  can be an on-card lower value cap, such as a 0.1 $\mu$ F PP or PS (which yields a corner of 66Hz).

Remove the original non-polarized electrolytic used for C<sub>5</sub> and

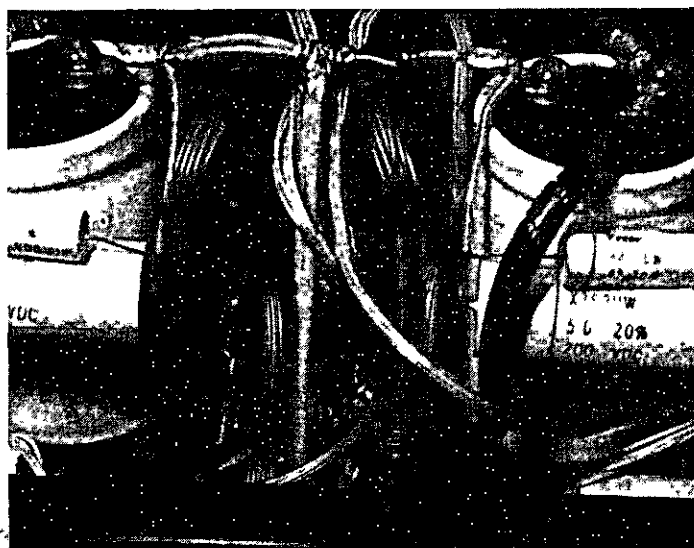


Photo 2: Closeup of G1; multiple parallel wires; C16, C17.

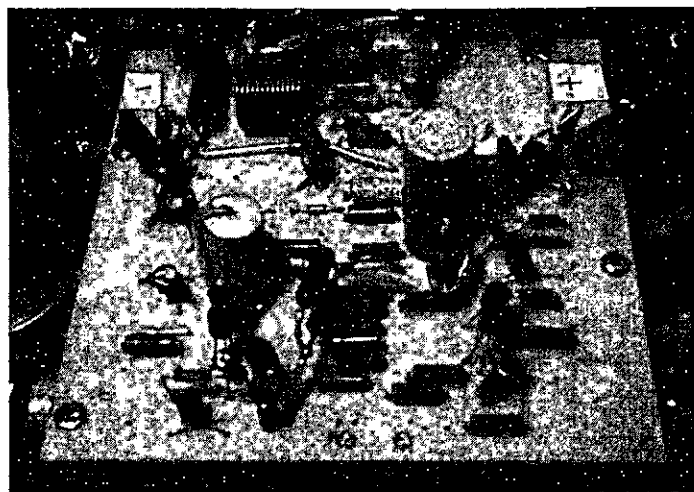


Photo 3: Restuffed PC-6 card.

FIG. 1B

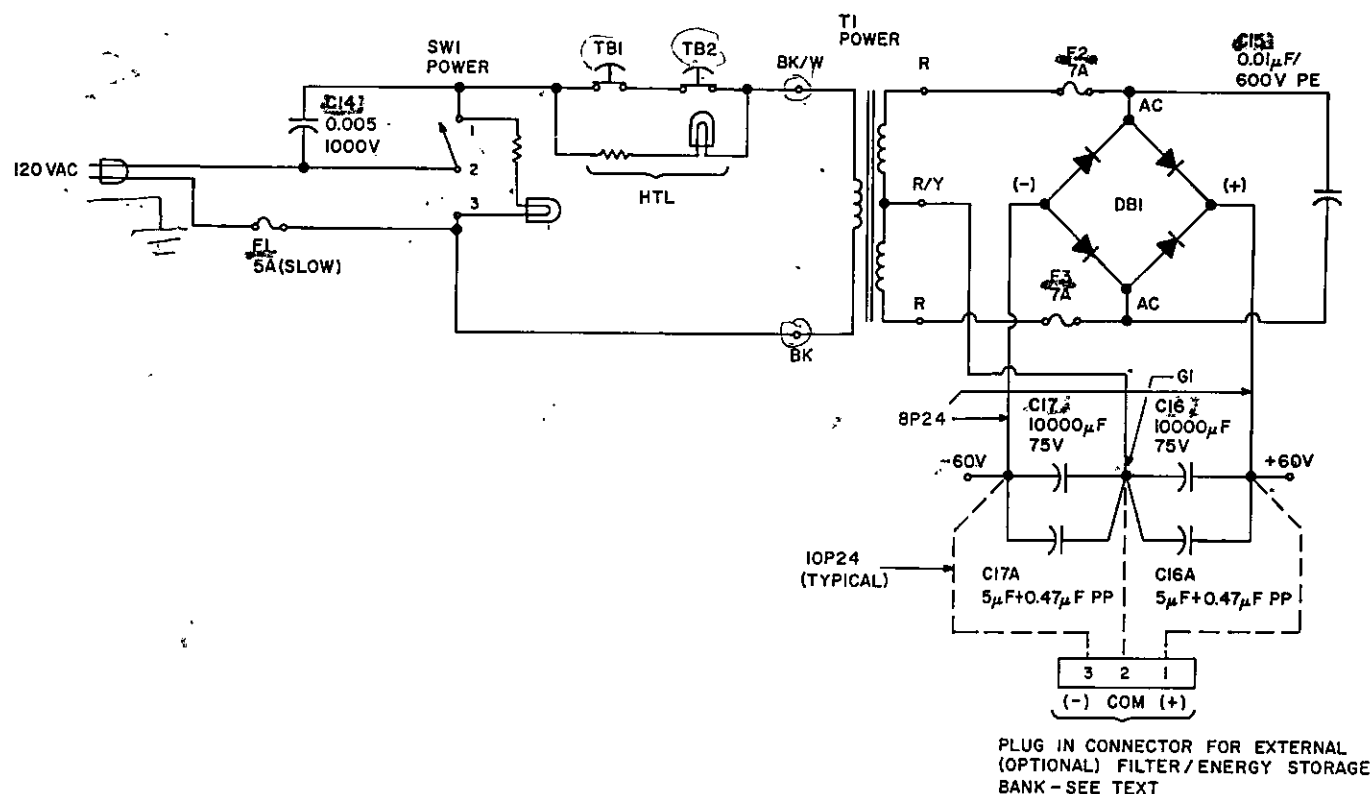


Fig. 1B. Schematic of the POOGE-2 power supply.

replace it with a high quality composite, on each of the two PC-6 cards.

Remove the 470µF/6.3V electrolytic from the PC-6 card. In its place substitute a low ESR, high quality electrolytic. Allow the leads to extend ¼" or so through the PC card, and solder. These lead extensions will be used to mount a shunt composite, inside the "U" of the heat sink (see Detail B). Note—if an axial lead unit is used for C<sub>5</sub>, be sure to use sleeving on the upper lead! Polarity is not critical.

Prewire a 5µF + 0.47µF PP shunt, using capacitors as specified in Step 3. Onto each lead of the 5µF cap, slip a length of #18 Teflon sleeving. Twist the ends of the leads into a hook, which will be wrapped around the ¼" electrolytic lead (above). You may do this now, if you intend to do no further work inside the heat sink. Solder securely, and dress the leads well away from R<sub>40</sub>-R<sub>43</sub> and the two-terminal strip. (Note 1. Take care that the soldering iron heat does not melt the outer plastic jacket of the shunts—if steps 7 & 8 are to be executed, these shunts will be best installed after Step 8).

The body of the 5µF PP may be rested against the outer wall of the heat sink, after attaching a small piece of foam insulation (weather strip type) (Note 2. This arrangement is admittedly physically fragile, and is not recommended for shipping-only for non-vibration home use).

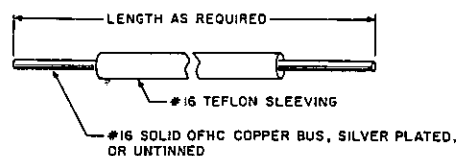
## 5. Cramolin MOSFET Sockets

On each heat sink module, carefully back out the mounting screw securing each MOSFET power transistor two turns, one at a time, and apply a dab of Cramolin, to both the under surface of the screw head, and to the thread portion (inside). After retightening these screws, apply a dab of Cramolin to each of the inner contact pins as well.

## 6. Replace Speaker Wiring and Fuses

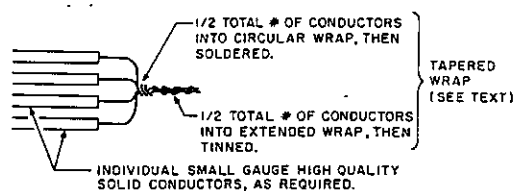
Replace the wiring to the speaker terminals with multiple parallel wires, and eliminate the fuse wiring altogether.

DETAIL D



a) Solid buss

### Wiring techniques



Suitable type: Solid OFHC copper, silver plated, with film insulation.

Schematic designation examples:

4P24 = 4 parallel wires, #24

8P24 = 8 parallel wires, #24

(See Table I for gauge equivalents; use sleeving or wire ties to snug up the bundle)

b) multiple parallel

Detail D. Schematic designation examples: 1SCB16 = single silvered copper buss, #16. 2SCB16 = dual silvered copper buss, #16. 1CB16 = single copper buss, #16 (all cases use sleeving)

Replace the speaker wires from each PC-6 pin 12 to the RED post with 8P24 wires, after preparing two 9" lengths, as described in *Detail D*. In *Step 10* we replace the wires to the BLK posts with 6" lengths of similarly prepared wires, soldered to the center of ground strap (see *Detail C*). Make sure that *all* individual wires of the 8P24 sets are soldered at both ends. Secure the individual wires of each set with either spiral wrap or sleeving, so that wires of the bundles remain together. See photo #2.

Remove the two wires to each fuseholder from PC-6, pins 8 and 11. On the top side of each PC card, mount a pigtail style 5A fuse, soldered to pins 8 and 11. On the reverse side of the card, solder a 0.1μF/100V PP capacitor, up inside the heat sink. If no pigtail fuse is available, use a single fuseholder (Littlefuse #357) mounted with a pair of 1CB16 leads, and clip into it a 5A fuse, with Cramolin applied. Dress this arrangement so that neither fuse terminal can touch the chassis when the amplifier modules are bolted up. Reduce the size of the fuse if your speaker requires it.

## 7. General Capacitor Rework

In this step, upgrade the smaller capacitors to a similar value, but with higher quality PS or PP film capacitors. Most of these are mounted on the two PC-6 cards, with some on the chassis. The following *Step (8)* performs a similar upgrade to resistors, therefore the builder may wish to combine these two steps into a common one, while the two PC-6 cards are separated from their heat sinks. A very large number of de-soldering and re-soldering operations are to be properly executed here; be absolutely certain that *each* component is replaced and resoldered carefully, and check for cold joints and solder splashes. Use *sleeving where appropriate*, on long leads. The general component requirements are listed for each reference designation.

Change capacitors in each channel as designated below. See photo #3.

- |   |  |
|---|--|
| ✓ C <sub>1</sub> see Step 3                       | ✓ C <sub>19</sub> same as C <sub>7</sub>   |
| ✓ C <sub>2</sub> 390pF ≥ 60V PS                   | C <sub>20</sub> , C <sub>21</sub> remove original discs, substitute new 0.1μF PP (as C <sub>7</sub> ), located as in Fig. 1, back of card (use sleeving) |
| ✓ C <sub>3</sub> , C <sub>4</sub> 1000pF ≥ 30V PS |  |
| ✓ C <sub>5</sub> see Step 4                       |  |
| ✓ C <sub>6</sub> 270pF ≥ 60V PS                   |  |
| ✓ C <sub>7</sub> 0.1μF ≥ 100V PP                  |  |
| ✓ C <sub>8</sub> 5μF ≥ 50V MPC (use sleeving)     | Notes: "PP" = polypropylene dielectric   |
| ✓ C <sub>9</sub> 560pF ≥ 60V PS                   | PS = polystyrene dielectric  |
| ✓ C <sub>10</sub> same as C <sub>7</sub>          | MPC = metallized polycarbonate dielectric  |
| ✓ C <sub>11</sub> 10000pF ≥ 60V PS                | PE = polyester dielectric  |
| ✓ C <sub>12</sub> same as C <sub>7</sub>          | See sources at the end of article.   |
| ✓ C <sub>13</sub> same as C <sub>2</sub>          |  |
| ✓ C <sub>14</sub> no change                       |  |
| ✓ C <sub>15</sub> 0.01μF 600V PE (use sleeving)   |  |
| C <sub>16</sub> , C <sub>17</sub> see step 10     |  |
| ✓ C <sub>18</sub> 47pF ≥ 60V PS                   |  |

## 8. Change resistors in each channel as designated below.

- |  |  |
|--|--|
| *R <sub>1</sub> see step 3 475K Ω                      | R <sub>28</sub> removed  |
| *R <sub>2</sub> 2.21k (2211)                           | R <sub>29</sub> 1k (1001) see step 9                                     |
| *R <sub>3</sub> 22.1k ((2212)                          | R <sub>30</sub> 475Ω (4750) 1/2 WATT                                     |
| R <sub>4</sub> 100Ω (1000)                             | R <sub>31</sub> RN65D2210F   |
| R <sub>5</sub> same as R <sub>4</sub>                  | R <sub>32</sub> same as R <sub>26</sub>                                  |
| R <sub>6</sub> same as R <sub>2</sub>                  | R <sub>33</sub> same as R <sub>4</sub>                                   |
| R <sub>7</sub> short (jumper)                          | R <sub>34</sub> removed  |
| R <sub>8</sub> 332Ω (3320)                             | R <sub>35</sub> no change  |
| R <sub>9</sub> 22.1Ω (22R1) 49.9Ω alter-nate, see text | R <sub>36</sub> no change  |
| R <sub>10</sub> same as R <sub>9</sub>                 | R <sub>37</sub> 10Ω (10R0) 1/2 WATT                                      |
| R <sub>11</sub> see step 11                            | R <sub>38</sub> RN75D 10R0F (or, 2x RN70D20R0F in parallel)              |
| R <sub>12</sub> 562Ω (5620)                            | R <sub>39</sub> see step 11  |
| R <sub>13</sub> same as R <sub>11</sub>                | R <sub>40</sub> same as R <sub>30</sub> †                                |
| R <sub>14</sub> same as R <sub>12</sub>                | R <sub>41</sub> same as R <sub>30</sub> †                                |
| R <sub>15</sub> same as R <sub>9</sub>                 | R <sub>42</sub> same as R <sub>30</sub> †                                |
| R <sub>16</sub> same as R <sub>9</sub>                 | R <sub>43</sub> same as R <sub>30</sub> †                                |
| R <sub>17</sub> same as R <sub>2</sub>                 | R <sub>44</sub> no change  |
| R <sub>18</sub> same as R <sub>8</sub>                 | R <sub>45</sub> same as R <sub>37</sub> ; see step 3                     |
| R <sub>19</sub> short (jumper)                         | P <sub>1</sub> retrimmed after all fixed resistors changed. (see step 9) |
| R <sub>20</sub> same as R <sub>4</sub>                 |  |
| R <sub>21</sub> same as R <sub>4</sub>                 |  |
| *R <sub>22</sub> same as R <sub>3</sub>                |  |
| *R <sub>23</sub> RN70D2211F 1/2 WATT                   |  |
| *R <sub>24</sub> same as R <sub>12</sub>               |  |
| *R <sub>25</sub> same as R <sub>4</sub>                |  |
| R <sub>26</sub> 1.82k (1821)                           |  |
| R <sub>27</sub> same as R <sub>4</sub>                 |  |

Notes: 1) All resistors 1/4 W, RN60D type unless specified otherwise. Complete PN as RN60DXXX-XXF, where XXXX is in parentheses. Ex. (2211) indicates RN60D2211F (2.21k, 1%). 2) \*Indicates most critical, do as a minimum. 3) See sources at end of article. 4) †Use a ground clip on MOSFET gate during soldering or skip these.

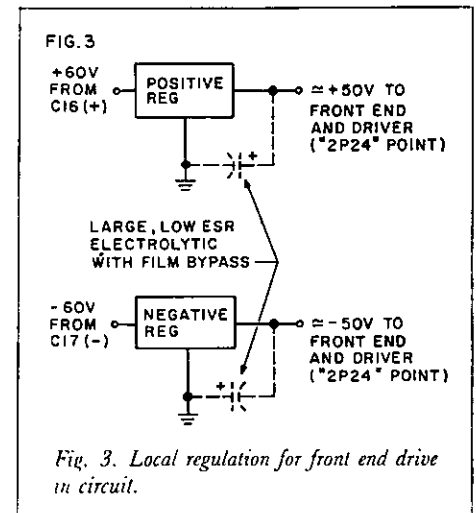
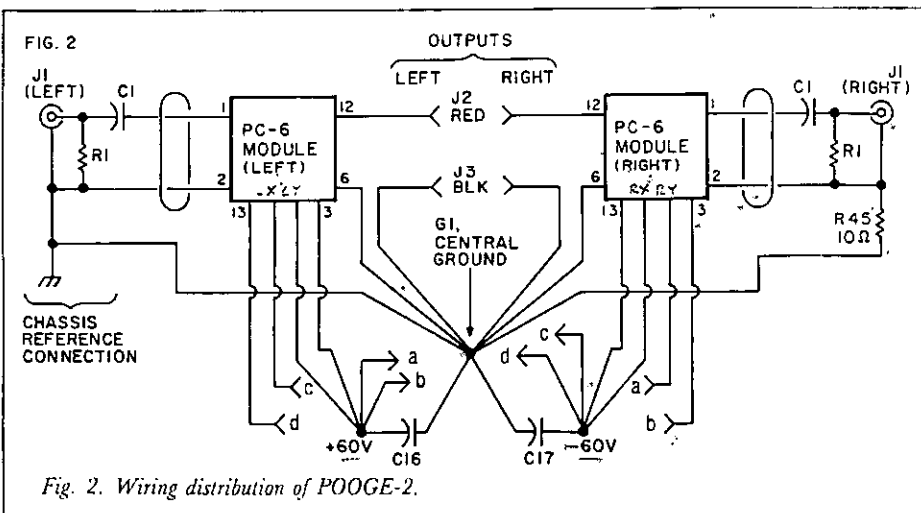
## 9. Reset Idle Current

Here we increase the idle current in each amplifier module more than 400mA, so as to provide increased small signal linearity, and what is essentially class A operation at low outputs. You can appreciate the benefits of this change examining the device's transfer curve in reference 14.

After the capacitors and resistors have been carefully replaced as per Steps 7 and 8, this step can be accomplished, *once the circuit's correct functioning has been verified*. By no means should the idle current be raised, if the amplifier shows anomalous behavior after Step 8; *troubleshoot and fix it first*.

Idle current can be most easily checked by removing the V+ fuse for a channel, and clipping an ammeter with a 500mA full scale setting across it (observing polarity of course). Switch on the amp, and after warmup observe the factory bias setting of 200-250mA. Adjustment of P<sub>1</sub> can raise this to 400mA or more. Adjust P<sub>1</sub> for a reading of

Continued on page 22



425mA, as monitored after at least a half hour of operation. Note that due to circuit thermal time constants, a given cold current reading will typically fall off somewhat, with warmup.

With a stable reading of 400 to 425mA (exact level not critical), shut down the amp, and snip  $R_{29}$ , without disturbing  $P_1$ . With an ohmmeter, carefully measure both  $P_1$  and  $R_{29}$ , record their resistances, and then remove them from the circuit altogether. Select a pair of metal film resistors so that their total resistance is equal to the total of that measured; and one comprises 75% of this. Install this resistor for  $R_{29}$ , and the other in the two end holes formerly occupied by  $P_1$ .

Re-apply power, monitoring idle current, which should re-stabilize to that set by  $P_1$  initially. Minor adjustment, if necessary, can be accomplished by trimming the " $P_1$ " resistor. Re-install the fuse into the fuseclip, and repeat this procedure in the opposite channel.

With this higher level of idle current, the two heatsinks will become noticeably more warm to the touch, but not dangerously so. Even higher levels of current might be desirable from a linearity point of view, but are not recommended, as the heat sinks can become quite hot, and even cycle the thermal breakers with heavy signal operation. Allow plenty of ventilation for the rebiased amp!

It is not absolutely necessary that this current trim step be done at this point in the overall sequence, but it is convenient, due to the fuseclips (removed in Step 10). If Step 12 is executed, we recommend that you recheck the idle current after its completion.

## 10. Filter Capacitor and Power Rewiring

Rework filter capacitors  $C_{16}$  and  $C_{17}$  (see Detail C) with attention to the associated wiring and fuses, to both lower and stabilize impedances in all supply lines. As a minimum, retain the stock 10000 $\mu$ F/75V capacitors, with the wiring rework. For a more complete power supply related update you may want to incorporate a filter bank or regulator, outboard (see main text and Step 12).

Remove the stock dual supply line fuse clips adjacent to the power transformer, the supply leads back to the filter caps, and to the PC-6 cards on either side. Study Detail D, then prepare four wire sets, two each of 7" and 12" lengths. Technique (a) is simpler, but lacks flexibility for access to the PC-6 modules. The parallel technique (b) is preferable (but tedious). Strip all wires as shown, and tin this 8P24 combination, solder the 7" lengths to pins 13-14 LEFT and pins 3-4 RIGHT, as shown in Detail C. Heat the PC-6 pin and insert the single extended wire through the pin, soldering it to the heavy track on the reverse side. Similarly, solder the 12" wires to pins 3-4 LEFT, and 13-14 RIGHT. Lightly twist the 8P24 wires through their length, and strip the opposite ends. Do not connect as yet.

As you can see by examining Fig. 1 we have eliminated the input stage decoupling network. The input stage feeds of +60V (2P24) and -60V (2P24) are fed either from capacitors  $C_{16}$  and  $C_{17}$  (eliminating the drop in the main  $\pm 60V$  lines (8P24), or from an input stage regulator which may be employed. If you choose the latter option,  $\pm 60V$  (2P24) feeds will be picked up in Step 12. Otherwise, proceed as follows.

In Step 8 above,  $C_{20}$  and  $C_{21}$  were replaced by 0.1 $\mu$ F PP caps, as were  $C_7$  and  $C_{10}$ .  $C_7$  and  $C_{10}$  mount where the 100 $\mu$ F/80V electrolytics were, and  $C_{20}/C_{21}$  on the back of the card. With this accomplished, then remove diode resistor network  $R_{26}-D_{11}$  from the component side of each PC-6 card; and similarly, remove  $R_{34}-D_{12}$  from each PC card. Clear PC holes on the  $D_{11}$  and  $D_{12}$  ends, nearest  $R_{27}$  and  $R_{33}$ .

Prepare four 2P24 sets, in lengths of 2 x 9"; 2 x 14". On one end of all pairs strip back  $\frac{1}{2}$ ", twist and tin.

Wire these prepared lengths as shown in Detail C, inserting the 2P24 wire into the PC-6 holes vacated by the  $D_{11}$  and  $D_{12}$  diodes, as follows: (see Hafler manual, p. 13):

LEFT PC-6:  $D_{11}$  cathode point, 14" wire; dress opposite end towards  $C_{16}$  (+), do not solder

RIGHT PC-6:  $D_{11}$  cathode point, 9" wire; dress opposite end towards  $C_{16}$  (+), do not solder

LEFT PC-6:  $D_{12}$  anode point 9" wire; dress opposite end towards  $C_{17}$  (-), do not solder

RIGHT PC-6:  $D_{12}$  anode point 14" wire; dress opposite end towards  $C_{17}$  (-), do not solder

On PC-6 ends, make sure all wires are well soldered, and there is no excess strain on the 2P24 wires. Slide a small piece of spaghetti over each 2P24 wire.

At this point (referring to Detail C) you should have from each PC-6 side a total of ten #24 wires; 8P24 to 13/14 or 3/4, and 2P24 to  $D_{12}$  or  $D_{11}$ . Group these 10 wires together at the  $C_{16}$  or  $C_{17}$  ends and dress towards  $C_{17}$  (-) or  $C_{16}$  (+), as appropriate. At the  $C_{17}$  (-) or  $C_{16}$  (+) terminals you should have two groups of 10P24 wires. Individual wires of these two bundle groups should be secured with  $\frac{1}{4}$ " spiral tubing, after slipping a piece of 3" spaghetti over wire bundle towards the PC-6, to strengthen it and insulate in areas near the PC-6 card. Trim the wires to an even length, and strip each.

Remove all hardware from all four  $C_{16}$  and  $C_{17}$  posts, and treat the terminals with Cramolin, wiping away any excess. Using a crimp lug such as the Thomas and Betts 1210 (12-10 wire gauge, #10 stud), crimp lugs on each of the 10P24 wire bundles at the  $C_{17}$  (-) and  $C_{16}$  (+) terminals. Prepare two 8P24 wire sets, and rewire the DB1 (-) and (+) terminals to  $C_{17}$  (-) and  $C_{16}$  (+), respectively. Solder at the DB1 ends, and use crimp lugs at  $C_{16}$  and  $C_{17}$  ends. Using new 10-32 x  $\frac{3}{16}$ " screws of an indium plated (preferred) or a non-ferrous such as stainless steel or clean brass material, connect the three wires to  $C_{17}$  (-) and  $C_{16}$  (+); as shown in Detail C. Double check wiring against the Fig. 1b power supply, and tighten the screws securely. Note that these screw lengths are for the stock 10000 $\mu$ F/75 capacitors, which use a low post type terminal, and provide maximum thread penetration. If a high post terminal capacitor is used, the screw lengths should be adjusted to suit.

With a 10" length of #16 copper buss, either untinned or silvered, fold it into a 5" long V. At the closed end, crimp on a lug and solder. Slide four 1" length pieces of #16 Teflon tubing over the two busses, and crimp and solder a single lug on the free ends. Mount this 2CB16 ground buss between  $C_{17}$  (+) and  $C_{16}$  (-), as shown in Detail C. Use new 10-32 x  $\frac{3}{16}$ " screws (see comment above for different materials and terminals), and tighten securely.

The center point of this new buss is the "star" ground reference  $G_1$ , where all amplifier commons come together. Solder the Red/Yel transformer lead to this center point, and the two speaker common (BLK) terminals using 8P24 wires, as shown in Detail C. A high wattage tip will be required to properly wet this joint. See photo #2.

Cut the red transformer leads from the two "AC" corners of DB1, and wire to the rear side of two newly installed (Littlefuse 357) single fuse clips (mounted on the inside ears of the  $C_{17}$  and  $C_{16}$  mtg brackets). Jumper the two output ends of these fuse clips to the DB1 corners, respectively, as shown. Install two 7.5A AGC fuses in these holders, using Cramolin. On the AC inputs of DB1, install  $C_{15}$  (using sleeving) as noted in Detail C.

Install a pair of composite 5 $\mu$ F + 0.47 $\mu$ F PP caps across  $C_{17}$  and  $C_{16}$ , as shown. Mount with minimum lead length, with their common point to center of strap, and solder securely. At this point double check all wiring before going further, for good solder joints and correct execution. (See Fig. 1a, 1b, and Detail C again.) Continue now to step eleven, before repowering.

## 11. Rewiring Ground

In this step we remove the ground connection between input and output sections of the PC-6 boards, rewire the input and output grounds into a star system, and remove the input stage bias string current from the input ground circuit.

Referring to Step 8 and Fig. 1a, lift resistors  $R_{11}$  and  $R_{13}$  on each PC card on their ends which connect to PC-6 pin 2 (see Hafler manual, p. 13 and 14). Connect these (now) floating ends of  $R_{13}$  and  $R_{11}$  together using solid wire, insulating the connections with two pieces

of sleeving. After soldering, slide the sleeving over the resistor body so that no un-insulated points are exposed, and dress the jumper neatly against the card.

Referring to *Step 8*, remove  $R_{39}$  (2.2 $\Omega$ ) from each PC-6 card. Referring next to *Figs. 1a, 2* and *Detail C*, note that an input ground to PC-6 pins 2 is provided by the wire from J1, L and R, common. Using two 10" lengths of 4P24, each with a jacket of sleeving over all, connect a wire from J1-L common (chassis references solder lug) to the G1 central ground. Similarly, a ground is provided to J1-R common through  $R_{45}$ , a 10 $\Omega$  resistor. Solder 4P24 wire to  $R_{45}$  securely and slide a larger piece of sleeving over it, then connect the other end of this 4P24 to G1.

Referring again to *Figs. 1a, 2* and *Detail C*, prepare two 10" 4P24 wires. Connect one to the LEFT PC-6 pin 6, the other to the RIGHT PC-6 pin 6 (after removing the original wires). Slide sleeving down over these wires up next to PC-6. Connect the free ends of these two wires to G1. Take care to solder these connections *very* carefully, as there are now seven wires connected to the buss (aside from the 2CB16). See photo #2 for G<sub>1</sub>, again. Recheck all wiring for compliance, and check for continuity from G<sub>1</sub> to PC-6 pin 6 (both sides), the chassis, PC-6 pin 2 (L), J1-L common; and 10 $\Omega$  to PC-6 pins 2(R), J1R common. Repower and bench check before listening. Alternately, power up with 1/2A line fuse temporarily (speakers disconnected). If amp passes this without fault, enjoy by listening.

## 12. Power Supply Changes

One can incorporate a variety of sonically valid power supply changes in a DH-200; the differences among these reduce to tradeoffs in cost/effort, with due allowances for physical limitations of space. The major options are outlined here, and the reader may select the most appropriate.

A. The power supply change requiring the least documentation for the audio amateur is an outboard (or inboard) *filterbank*, to lower buss impedance, increased energy storage, and reduced non-linear crosstalk components.<sup>50</sup> This can be applied to the DH-200 as outlined in (32), but surge turn-on limiting is strongly urged. Also, you should install the Litz-type wiring as outlined above, with 10P24 conductors suggested, of minimum length. Indium plated hardware for screw-terminal capacitors is also suggested, as discussed above in *Step 10*. The plug to attach this filter bank can be located just behind the diode bridge, to keep lead length down. If you opt to use low ESR internal caps, space will be necessarily limited. The *Sources* listing, p. 26, specifies a low ESR/ESL 10000 $\mu$ F/75V cap suitable for  $C_{16}$  and  $C_{17}$ , and physically compatible.

B. A minimum effort in terms of cost and size incorporates *local regulation*, to stabilize the front end and a simple emitter-follower "capacitance multiplier," to more sophisticated types. For example, the POOGE-1 regulator (*Fig. 6*) can be set up for  $\pm 50V$ , using a complementary (-) regulator. In terms of ready board availability, the modified Boak regulator<sup>51</sup> will be more attractive. Note—since only 20mA or less of current is necessary per rail of each PC-6 card, you can adapt this circuit (p. 44) for lower power operation, using only light transistors.

For any of the three options mentioned, a pair of (-) and (+) regulators is needed for the stereo channels. Electrically, these go between the unregulated  $\pm 60V$  rails, and the regulated  $\pm 50V$  which feed the front end plus the driver circuit. With reference to the original circuit, the regulators go functionally where the diode/resistor networks were. This will be clearer after study of *Fig. 3*.

An important consideration in using any of these schemes is holding the HF impedance low, indicating good HF bypassing at the output, by installing a large, low ESR cap. To fit on the PC-6 a unit from the Sangamo 301 or 350 series is suitable. If you go off card, a large 600 $\mu$ F or more photoflash type is effective. If this impedance (> 1k $\Omega$ ) is not held below 50 milliohms, clarity and detail will not be preserved in the amp's reproduction, although the regulator can still be useful at low frequencies by producing increased impact, punch, and separation (these latter factors are a major result of the regula-

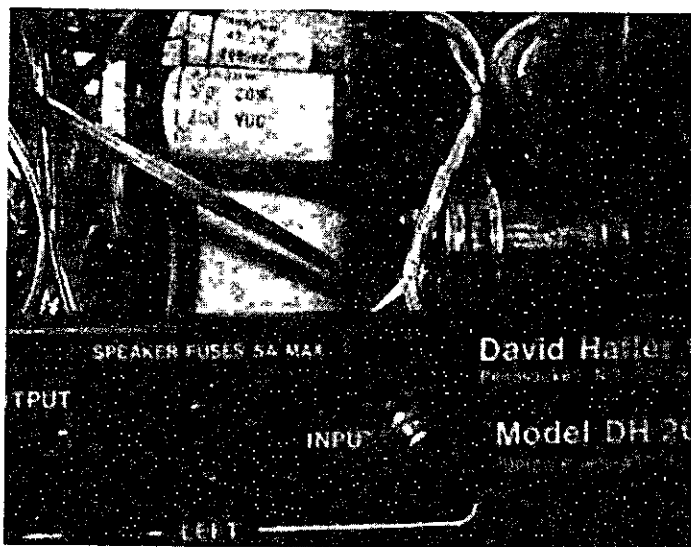


Photo 4: Closeup of input/output jacks, added bypass capacitor.

tion). Note that the non-regulated hookup just as shown in *Fig. 1a* will preserve good HF range reproduction with low ESR caps (at the expense of some sacrifice in bass dynamics) and may be preferable for its simplicity. See photo #4 for added capacitor.

C. The options discussed in B. are incomplete in terms of regulation, in that they only provide stabilization of the front end/driver circuits. Complete regulation can be achieved by employing Jim Boak's design, as he outlined in *TAA*, 3/81. With this choice, the space problem becomes acute, and the transformer is best outboarded with the regulators inside. This approach affords virtually complete isolation of the four voltages, at any power output.

For this step to be fully effective, some additional (unregulated) rail voltage is advisable, so as to not compromise max power output (see Jim's discussion<sup>6</sup>). We also believe this additional power has virtues in the form of a huskier power transformer, with an output in the range of 80-90V<sub>ct</sub>, at a current of 6A (or more). The Signal 88-6 is suitable with series connected secondaries yielding 88V<sub>ct</sub> @ 6A. It also fits into the DH-200 chassis (with new mounting holes); but if this unit is used the *Fig. 4* hum reduction strap *must* be added (if not factory present), and the wiring must conform to *Fig. 2* to avoid ground loops and resulting hum. The tapped primary of the 88-6 allows voltages at the secondary to be optimized.

To achieve more effective primary power, some rework of the high temperature thermostats is desirable. Most simply, use the thermostats in their present physical locations, but wire them electrically into the coil circuit of a husky contact (> 10A @ 120VAC rating) power relay. Note that this approach will allow you to reduce the transformer primary circuit to a protective fuse, and this relays' contacts, if the present power switch is used to control the relay coil. You can also use a DC relay coil, and remote your on/off.

### The best choice?

Choosing from the above list of options can be a bit overwhelming, so we'll try to give our impressions regarding a most-for-least choice. We believe this is the substitution of the new transformer with increased current reserve, inside the existing chassis, with front end regulation and the good HF bypassing noted. Interestingly, even *without* the front end regulator, the amp seemed to us to take on a new, more robust and dynamic character in the bass region especially. Transient dynamics became sharper, and what before seemed a relatively compressed sound opened up and became more lifelike. We think the greater headroom available into low impedance loads and the greater (linear) flux capability of the new transformer are responsible for the change.

Accordingly we suggest the transformer, for those interested in improvements in the areas noted. All those who did field executions and performed the transformer change had reactions similar to ours above, and that of Rod Rees. For those interested in an all out power



FIG. 4

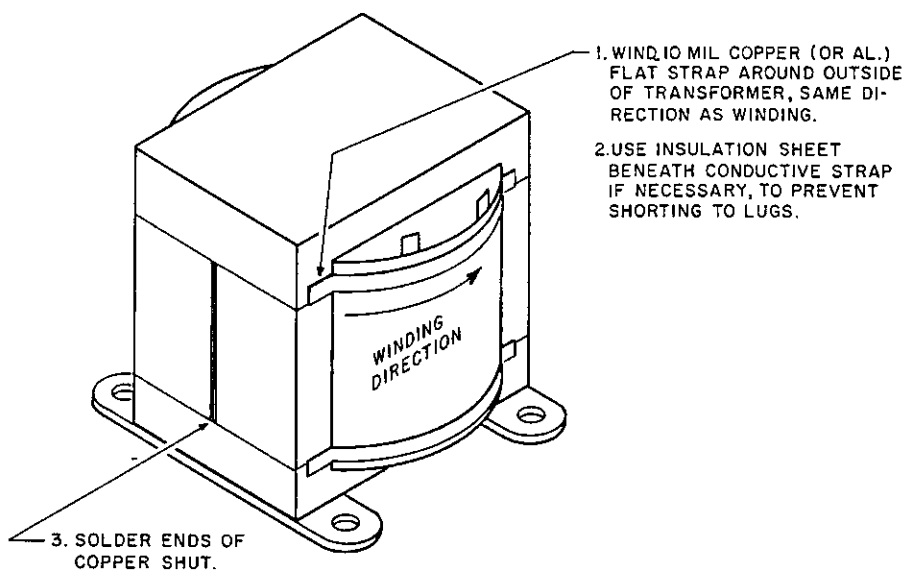


Fig. 4. Hum reduction shield for power transformer suggested by N. Hansson of Signal Transformers.

mod, we suggest Boak's outboarded raw supply, with the four internal high power regulators and interconnections via short Litz type wires.

## CONCLUSION

We have provided in the POOGIE-2 one example of how to improve your amplifier's performance from a number of perspectives. A major point we hope to have made is that these improvements are possible, without changing transistors, topology, or in (static) measured performance.

The Hafler DH-200 was chosen as a vehicle to demonstrate the validity of such changes, but we hope it is clear that they are also applicable to other audio products. Indeed, in many other amps such mods may be even more effective, since so many are less satisfactory, at the outset. And, we would hasten to add, the fact that we chose to modify the DH-200 should by no means be taken to infer any poor quality in its original form. What we have shown is how to make a generally good and highly modifiable amp appreciably better, on a relative basis, and to illustrate that the specific choice of optimum components, materials, layout and/or wiring can have an effect on the sonics (in addition to those better understood factors such as circuit topology).

We are well aware that different people can have radically different perspectives on audio, in a variety of contexts. What we may describe as sounding like one thing may not be perceived similarly by some others, while yet others might react even more favorably than we do. Many, many factors are pertinent to audio, and a great many of them are

well understood, quantifiable and predictable. But unfortunately, this is a far, far cry from the state of *everything* being well understood, totally predictable, and exact.

It seems that the lifelike and totally realistic reproduction of music as a branch of the audio enterprise is one of those vexing paradoxes where we continue to uncover more and more of our ignorance relating to this goal. These authors think this goal is a most worthy one, worth fighting for, in fact. We don't think we've yet reached the goal of total facsimile reproduction by any means, and in many ways we're dismally far from it. To take just one obvious and simple example, is it an unreasonable criterion to ask an audio system that it never fatigue, regardless of the musical material or length of exposure? Until we can reach some semblance of this goal, it seems pointless to come forth with any absolute or rigid statements.

As we noted initially and as Rod Rees reports, some of the changes made in the POOGIE-2 reveal more information from within the signal. We feel this is a demonstration of reducing the effects of the masking phenomenon, and suggest that some of the techniques we describe may be useful towards more complete exploration and ultimate understanding of our hearing processes. We also believe there is need for more complete control of tests involving listening comparisons, in such specific areas as conductors and wires, for example. And certainly it is a worthwhile and sensible goal to structure tests to simulate in all relevant aspects actual listening for pleasure (what we do with our systems day-to-day). We hope the audio community may soon begin to work together towards better controlled tests.

Of course the dialogue of subjective testing will not end with these statements. The POOGIE-2 will be available to those hardy audiophiles with the yen to explore, and im-

prove their systems a few steps further. This we see as the true spirit of the audio hobby, not as proof of any particular view, but rather as the cooperative exploration of lesser known factors, for mutual benefit.

For whatever it is worth, we believe the mods above, applied to a DH-200, can result in an amp with excellent sonic capability—better, in fact, than many more expensive units. But that's simply our opinion, not a guarantee that you'll be enthralled, or consider your time/cost expenditure worthwhile. We wish you well with the mods to your DH-200 or other amps and hope you will share your experiences with your fellow readers. So, keep on POOG'N! □

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### SOURCE INFORMATION

The following data is furnished as a service to the readers of this publication as information only, and mention of a specific supplier does not constitute an endorsement of that firm's product. The authors have no financial involvement in any of these firms, and also cannot be responsible for their business practices.

#### Litz wire

- ✓ Bridgeport Ins. Wire Co.  
51 Brookfield Ave.  
Bridgeport CT 06610
- ✓ New England Elec. Wire  
365 Main Street  
Lisbon NH 03585

#### Wire-wrap wire

- Bulk (Kynar)
- ✓ Brigar Elect.  
10 Alice Street  
Binghamton NY 13904
- ✓ ✓ Elect. Man. Services  
1851 Reynolds Ave.  
Irvine CA 92714
- ✓ Intl. Components Corp.  
Box 1837  
Columbia MO 65205
- ✓ Precut, prestripped (Kynar)
- ✓ ✓ Elect. Man. Services Corp.  
1851 Reynolds Ave.  
Irvine CA 92714
- ✓ Intl. Components Corp.  
Box 1837  
Columbia MO 65205

#### Assembled cables

Geostatic Corp.  
226 Vreeland Ave.  
Paterson NJ 07504

Mendota Research  
c/o Karen Richardson  
2985 College Ave.  
Berkley CA 94705

#### Crimp lugs

Thomas and Betts  
Amp. Inc.

#### Binding posts

Superior BP30† (Allied, Newark, Hanifin)

#### RCA Jacks

Old Colony

#### Fuseclip

Littlefuse 357001† (Hanifin, Newark)

#### Transformers

Signal Transformer  
500 Bayview Drive  
Inwood NY 11696

#### Capacitors

PP: TRW, Wesco  
PC: Wesco  
PS: Mepco/Electra  
Electrolytics; for:  
C5 Sangamo 301EN102U012B2  
C16/C17 Sangamo  
139R103U075BC2B (high post term). Filter bank use-see ref. (32): source below

#### Hardware

Brass, stainless steel

Aerospace Requirements  
457 E 18th St.  
Paterson NJ 07514

#### Assembled filter banks

Taylor House  
Box 140  
Denver NC 28037

#### Indium plated screws

Old Colony.

#### Distributors

- ✓ All Elect.  
Box 20406  
905 S. Vermont Ave.  
Los Angeles CA 90006
- ✓ Allied Elect.  
401 E. 8th Street  
Ft. Worth TX 76102
- ✓ Fair Radio Sales  
1016 E. Eureka Street  
Box 1105  
Lima OH 45802
- ✓ Hanifin Elect.  
Box 188  
Bridgeport PA 19405
- J. Meshna  
Box 62  
Lynn MA 01904
- ✓ Newark Elect.  
500 N. Pulaski Rd.  
Chicago IL 60624
- ✓ Old Colony Parts  
Box 243  
Peterborough NH 03458
- ✓ Tek-El  
Box 2361  
Woburn MA 01888

#### Resistors

Corning Glass Works  
550 High St.  
Bradford, PA 16701

#### OEM Suppliers

Corning Glass Works  
550 High St.,  
Bradford, PA 16701

Mepco/Electra  
Columbia Rd.  
Morristown NJ 07960

TRW Capacitors  
301 W "O" Street  
Ogalla NB 69153

Sangamo Capacitors  
PO Box 128  
Pickens, SC 29671

Wesco Capacitors  
201 Munson Street  
Greenfield MA 01301