High Quality Headphone Amp

A Sophisticated Class-A design by J. Linsley-Hood

LISTENING with headphones offers a curious mixture of advantages and limitations which is not always apparent on initial acquaintance. On the credit side, properly designed headphones can have a bass response substantially better than can be obtained in a normal-sized living room, where the loading characteristics of the enclosed volume of air make it increasingly difficult for a conventional loudspeaker system to generate true low frequency pressure waves without substantial distortion. Also, again assuming proper design, the small mass of the driven diaphragm of the headphone and the absence of room reflections allows a cleaner and more transparent treble than can normally be achieved in the domestic environment. Finally, the absence, normally, of crossover networks and spatial incoherence between the transducers leads to a more uniform spectral distribution with headphones than is attainable with even the best of speakers.

On the debit side, the absence of any perceived sound field in which the listener is situated, and the occasionally unwelcome weight and restriction in movement imposed by headphones, tend to make prolonged listening through these a more artificial experience than through even a relatively inferior pair of loudspeakers.

From the point of view of the amplifier designer a different set of considerations exist, and these almost entirely favour the use of headphones—because of their light loading and often high load impedance—and make it possible to envisage simple amplifier designs free from the performance constraints implicit in the nature of higher power systems. This freedom from the need to accept some degree of performance compromise, if coupled with a phono preamplifier of appropriate quality, can reveal unsuspected nuances and subtleties of detail in ostensibly familiar recordings which can be quite astonishing on first experience.

I recall two instances of this type during trials of an RIAA/headphone-amp, made as a Christmas present for a friend, both with recordings I thought I knew well. In one of these I could distinctly hear someone, perhaps the conductor, periodically turning over the pages of his score, and in the other, on a well liked and frequently played disc, one could distinctly hear, about half-way through the second side, the noise of a music stand falling to the floor, accompanied by a muttered 'Oh d . . n'. (Presumably neither the producer nor the engineers responsible for this disc had heard this on replay, or it would have been removed on editing.)

So, wearing my amplifier designer's hat, I feel that the benefits which can accrue to the use of good and well designed headphones (and these benefits are substantial) will only be partly realised if they are hung on the back end of a power amplifier whose design has mainly been optimised to provide large powers, safely, to low impedance loads.

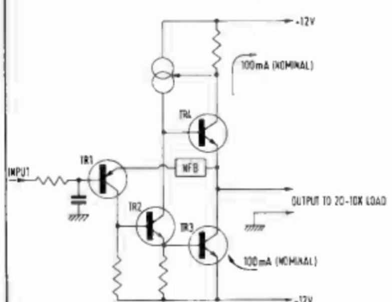
Design of headphone amplifier

There is a considerable, and justifiable, interest at the present time in the fact that similarly specified power amplifiers can sound different to one another. This is more surprising to the layman than it is to the amplifier designer, who knows the performance compromises which have been made in the design, both as a result of the impossibility of reconciling mutually conflicting design requirements, and as the result of commercial pressures to keep costs down. Naturally, the designers (some of whom are mainly in it for the money) are not going to admit that their achievements are in any way short of perfection, but nevertheless this is the sad truth. The actual sound of the unit then reflects, to a degree which depends on the perceptiveness of the listener and the quality of his reproduction environment, the nature of the balance of compromises chosen by the designer.

I note, with some regret, that I am still 'out on a limb' in my choice of the order of importance of defects, in relation to my co-workers in this field, and it is therefore pleasant to be able to put together a circuit design which not only satisfies the conventionally chosen (and to my mind largely irrelevant) performance requirements, but also, to a fuller extent than normally feasible in a high power design, the requirements which I think to be musically desirable.

These are, not necessarily in precise order of importance: the absence from the distortion component residues of the amplifier of any significant amount of high-order (7th, 9th, 11th, etc) harmonics, particularly when these are of 'odd' order; the absence of the intermodulation products due to these high-order components, particularly when these arise from discontinuities in the transfer characteristics of the amplifier around the central (low signal level) regions; the complete absence of glitches, overshoots and 'hang-ups' in the transient response, especially on reactive load (*ie*, real-life) conditions; the absence of significant slew-rate limiting and transient intermodulation effects, again particularly when these arise on real-life type loads (as distinct from the artificial, laboratory-type, loads on which systems are so often specified and reviewed); and the absence of any load-induced or shock-excited instability—be it never so fleeting in duration—arising from the incautious use of excessive feedback bandwidth in the pursuit of impressive high frequency THD figures. To these prohibitions I would add, in a more positive sense, a plea for a rapid 'turn-on' time, to avoid loss of desirable signal detail, a rapid 'settling' time, as a measurable guarantee of good transient response, and a square-wave reactive load response which is smooth and does not add to the transient energy.

FIG.1 SCHEMATIC DIAGRAM OF CLASS-A POWER AMPLIFIER

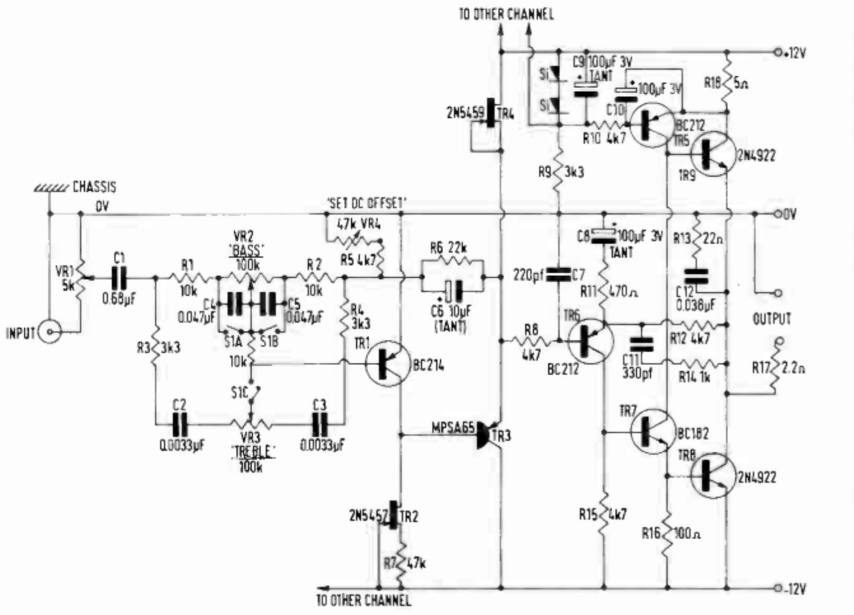


(Output transistors dissipate 1.2 watts each and are mounted on small heat-sinks)

This is a fairly formidable 'shopping list', which is not met by any commercial amplifier within my knowledge to an extent which I would regard as adequate, especially in respect of reactive-load transient behaviour. The things which are often found and, I think, only of value in impressing the gullible, are THD values at 15 or 20 kHz of the order of 0·1% or less (and I've never found anyone who could hear the second harmonic of 20 KHz, let alone the third) and S/N ratios of 70 dB or more, referred to a relatively low-level signal. Quite apart from the fact that there is virtually no readily available programme source which could match this specification, to make use of it would demand a dynamic range which is currently beyond our grasp.

The purpose of this homily is not simply to provide me with an opportunity for grumbling at the state of contemporary amplifier design (although I do admit that it is enjoyable to do so), but to indicate the nature and extent of the problems which are there, so that one might more clearly see the ways by which the low power requirements of the typical headphone untie the hands of the designer. In particular, the relatively low power demands of the headphone allow the use of a Class-A design, and this can, moreover, be of a

FIG. 2 HEADPHONE AMPLIFIER (LEFT-HAND CHANNEL SHOWN)



NOTE: Switch S1A, S1B, S1C is a tone control 'cancel' facility

single-ended, rather than 'push-pull' configuration. The use of Class-A completely eliminates the high odd-order harmonics which it is so difficult to remove fully and permanently from Class-B, and the avoidance of the conventional push-pull layout ensures both that such harmonics as do remain will be low order and 'even', and that the bends in the transfer characteristic are well away from the central 'small-signal' region. This, in turn, leads to a much more favourable distribution of the steady-state intermodulation products, with an associated transparency of tonal quality seldom otherwise attained.

In addition to this, the fundamental linearity of the Class-A system permits the use of much lower orders of negative feedback for a given THD level. While NFB is not, of itself, a bad thing, the use of it in large amounts does require a great deal of care in design—it is, in truth, the electronic engineer's tight-rope—and it does impose a number of restrictions in respect of the high frequency loop characteristics, which can only be solved as a compromise in one way or another. If one can get away with less, so much the better, and so much the easier to achieve a good, fast, clean, transient response without penalties in THD or reactive-load behaviour.

Finally, the use of Class-A, with the output stages allowed to draw a substantial, and largely constant amount of current permits, in the case of transistors, both rapid small-signal turn-on times (because the transistors are operating under conditions in which the HF performance is not impaired) and also fast turn-off response (because to turn off the signal does not necessitate turning off the transistor, with all the complications arising from hole storage and carrier re-combination). This gives a characteristic aural response only obtained with some difficulty by other means.

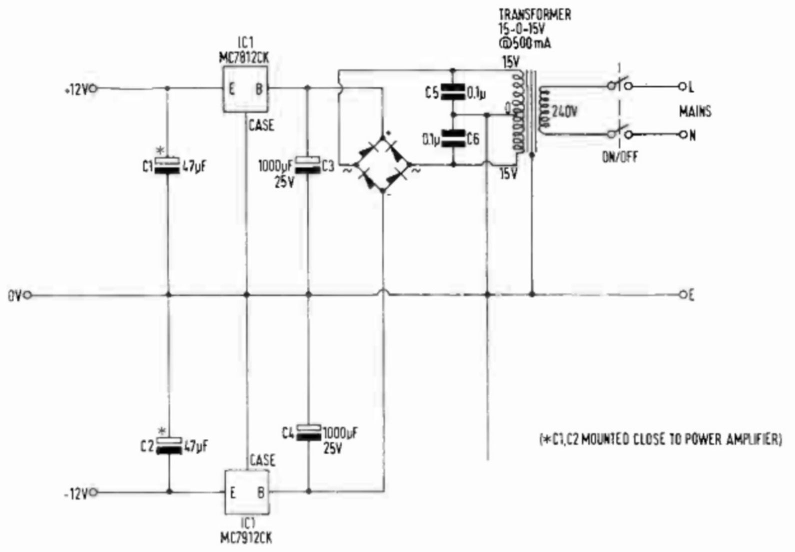
Circuit design

The circuit of the 'power' amplifier is shown in schematic form in fig. 1. This is basically a Class-A transistor amplifier stage (TR_2) driving an output emitter-follower (TR_4), which has an active emitter load (TR_3) also driven by TR_2. A constant-current source coupled to TR_4 serves both as a load for TR_2 and as a means of maintaining the output stage operating current at a constant mean value.

An input transistor amplifier (TR_1) serves to provide a somewhat larger loop gain and to restore the signal input level to near the '0 volt' line, since in this case it is intended to operate the amplifier in a direct-coupled form. Because all the transistors employed have high transition frequencies, and the loop stability—because of the very modest open-loop gain—is very high, no formal HF compensation, such as the ubiquitous and deplorable capacitor normally included between base and collector of the second amplifier stage (in this case TR_2) is necessary for stability. Consequently, neither slew-rate limiting of transients nor TID can occur. However, because it is neither necessary nor desirable that the amplifier should have a bandwidth extending into the MW radio band, an input CR integrating network is included in the amplifier, which gives a smooth roll-off in the HF response beyond 50 kHz. The closed-loop gain of the amplifier is also reduced from 10 (its low frequency value) to about 3 beyond this frequency by means of a step network connected across the feedback resistor. This is to minimise the risk of HF instability within the 'power' amplifier because of inadvertent proximity between output and input leads.

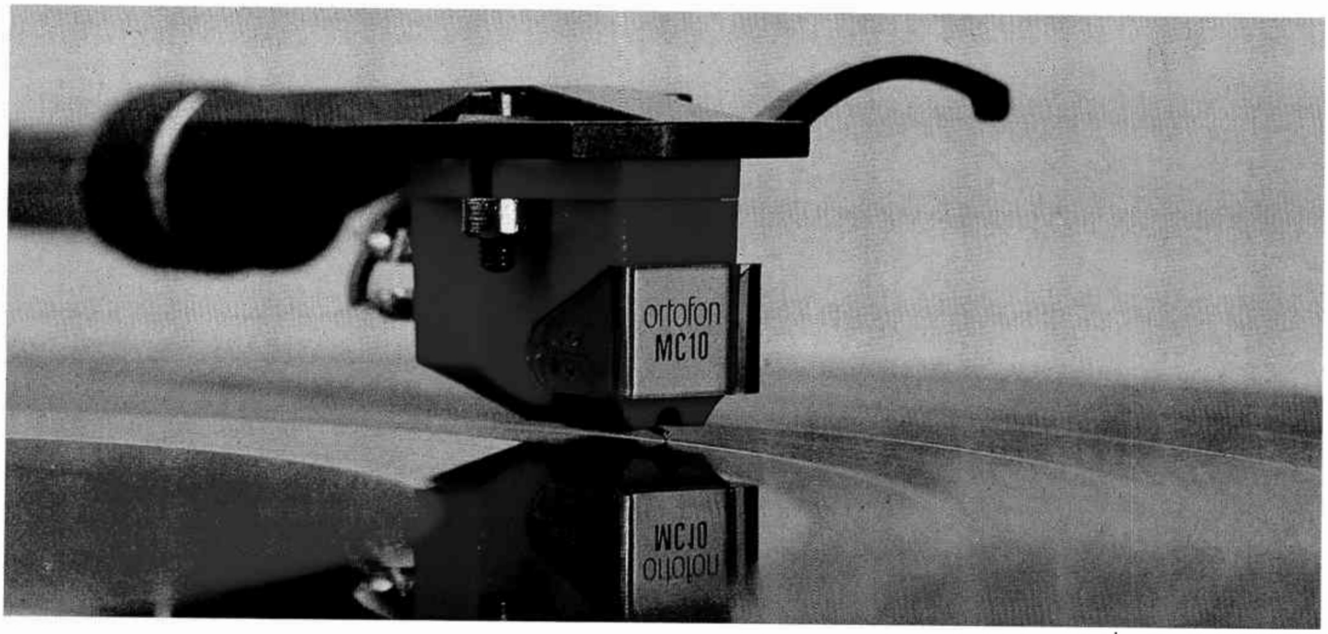
If all that is required is an amplifier having a 'flat' response, and an adequate power output to drive all normal headphones, the slider of the input gain control can be taken, via a suitable input capacitor-resistor network, directly to the input transistor (TR_6 in the complete circuit diagram). However, it was felt that some scope for tonal balance adjustment would increase the versatility of this design, and so a simple, but high quality, 'tone-control' circuit has been appended at the input. This is based on a Liniac arrangement, improved somewhat by the use of a *p–n–p* input transistor and a very high gain *p–n–p* Darlington emitter-follower with an

FIG. 3 CIRCUIT OF POWER SUPPLY FOR HEADPHONE AMPLIFIER



NOTE: IC1 and IC2 are TO3 type Integrated-circuit Voltage regulators mounted directly on chassis

MC 10
MOVING COIL REALISM AT A REALISTIC PRICE



There are as many expert opinions on HiFi as there are experts. With all the variables, an incredible range of systems can be produced and all have their different advantages but almost all experts agree that moving coil is superior to magnetic construction for cartridges.

Moving coil's detailed reproduction of spaciousness, three dimensional imagery and startling transient response surpasses that of even the best magnetic cartridge.

There is really only one choice if you wish to take full advantage of the capabilities of your HiFi system. Until now the high cost of the hand built moving coil cartridge has kept peak performance beyond the reach of all but the most wealthy.

Now Ortofon who have continuously developed moving coil technology since 1948, are able to produce a moving coil cartridge at a price which compares to the cost of medium quality magnetic cartridges.

Ortofon's long experience of cartridge design and manufacture make the finest reproduction available to all discriminating listeners with the MC 10 moving coil cartridge.

The MC 10's cantilever has been designed on new principles, making it easier and faster to produce. It is as light and as rigid as possible, utilizing a new aluminium alloy. The new cantilever design, together with a tiny, specially polished diamond, gives a very low stylus tip mass, excellent tracking ability, easy handling of transients and minimal record wear.

Owing to their small output voltage and low inner resistance, moving coil cartridges cannot be connected directly to a conventional phono input and it is therefore necessary to boost the signal.

MC 10 Cartridges are available separately or in a cost saving pack complete with the specially developed STM 72 step-up transformer for perfect matching to your amplifier.

Ask your dealer for a demonstration or write to:-

ortofon
accuracy in sound

harman UK
St. Johns Road, Tylers Green,
High Wycombe, Bucks. HP10 8HR
Telephone: Penn (049 481) 5331

FET constant current source as its emitter load. The design of the tone control stage allows a lift and cut of the bass and treble of about 12 dB. The overall distortion through the circuit is negligible. Switches S1A, S1B and S1C are included to allow a 'tone control cancel' facility. The complete circuit—for one channel—is shown in fig. 2.

Power supply

Many otherwise excellent amplifier designs are let down by unexpected and unsuspected breakthrough from the HT lines to the signal circuit inputs. This has been a factor which has been very much in mind in this design, and FET constant-current sources have been used where supply line isolation has been desirable. The need for supply line isolation is also greatly assisted at relatively low cost by the use of a pair of integrated voltage stabilisers, chosen to give a ±12 volt supply, having a very low output impedance and very low noise and ripple. The operating current of the output stages is automatically held to about 110 mA, giving a total current demand of about 250 mA for the two channels. At this load the use of 'T03' style voltage regulators is preferred. The circuit diagram is shown in fig. 3.

Performance

As indicated above, the aim of this circuit was to take advantage of the design freedom conferred by the relatively low load demands of the normal headphone, and to design a system free from the constraints and compromises inherent in normal power amplifier circuits. It is hoped, therefore, that this will be regarded not as a poor man's substitute for a power amplifier, but rather as a reference standard against which existing higher power units can be judged ●

A matching RIAA pre-amp designed to feed the input of the headphone amp. will be following shortly. **Ed.**

Performance data

T.H.D.
(Exclusively 2nd harmonic) (Includes noise)

100 Hz	0·014%
300 Hz	0·007%
1 kHz	0·008%
3 kHz	0·017%
10 kHz	0·044%

Measured at 1 V RMS across headphones having 100 ohms (nominal) impedance.

Turn-off time and turn-on time. Less than 0·5 µs

Rise-time. 4 µs. *Fall time.* 4 µs.

Settling time. (To within 1%) 6 µs—not affected by load reactance up to 0·22 µF.

Recommended Load Minimum 8 ohms; ideal 35 ohms to infinity.

Headphone amplifier parts list (1 channel)

Resistors	*Capacitors*	*Semiconductors*
2·2 Ω	220 pF	BC182
5 Ω	330 pF	BC212 2 off
22 Ω	0·0033 µF 2 off	BC214
100 Ω	0·038 µF	2N 4922 2 off
470 Ω	0·047 µF 2 off	2N 5457
1 k	0·68 µF	2N 5459
3k3 3 off	10 µF tant	MPSA 65
4k7 5 off	100 µF 3V tant	IN914 diodes 2 off (or equivalent)
10k 2 off		
22k		
47k		

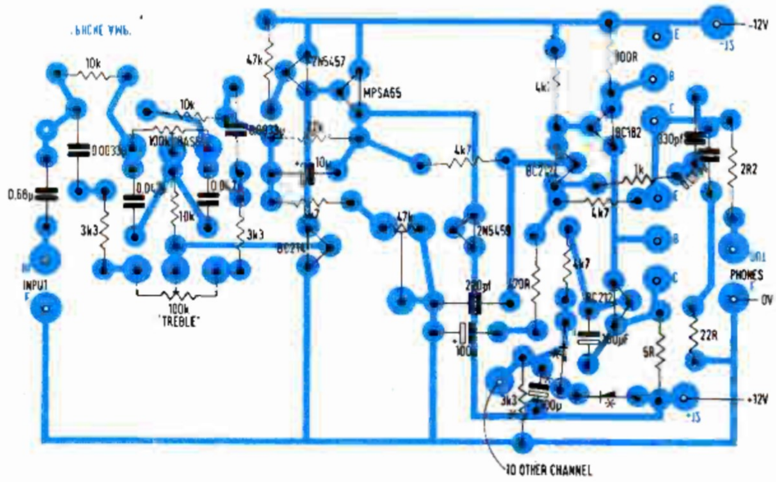
Potentiometers: 5k log, 100k lin 2 off, 47 k preset

Power Supply parts

Semiconductors	*Capacitors*
MC7812 CK	47 µF 15 V Elec. 2 off
MC7912 CK	1000 µF 25 V Elec 2 off
Bridge rectifier (1A 50 PIV) (or 4 x IN4001)	0·1 µF 2 off

Transformer 15-0-15 V 500 mA
Mains Switch 240 V 2 pole 1 way

FIG. 4 HEADPHONE AMPLIFIER (One channel only shown - Other channel identical)



COMPONENTS MARKED ✳ ON ONE CHANNEL ONLY

COMPONENT LAYOUT (Component side)

HEADPHONE AMPLIFIER P.C. BOARD LAYOUT (One channel only shown)