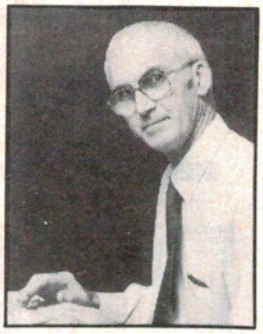
FORUM

Conducted by Jim Rowe



Should hi-fi amplifiers be earthed or not?

For best performance, high gain amplifiers really need to be earthed. Yet for the last few years, many manufacturers of domestic hi-fi amplifiers have been supplying them as "double insulated" appliances, so that legally they mustn't be earthed!

Perhaps the trend had actually started before I took my leave from *EA* back in late 1979, but if it had, I certainly hadn't noticed. I could have sworn that the vast majority of hi-fi amps were still at least nominally earthed, via the familiar 3-wire mains cord and 3-pin plug.

But now, coming back after a few years of playing with computers, I've discovered that just about all of them have become "double insulated". Apart from anything else this means they have the distinctive "concentric squares" symbol on the back, and are fitted with a 2-wire cord and 2-pin plug. And not only are they not earthed, but the law says that this kind of appliance *must not* be earthed . . .

It's all very interesting. Not so long ago, it used to be accepted wisdom that earthing of high-gain amplifiers was virtually essential, in order to get the best performance — lowest hum, minimum pickup of external noise, and so on. Of course the earthing had to be done carefully and correctly, to prevent introducing other problems such as hum loops and feedback via common impedances. This generally meant having only one "master" earth for the overall system, usually via the amplifier itself, with everything tied back to that as reference.

Now as far as I'm aware, the basic physical laws that used to operate in this area still apply today. Yet the fact remains that the majority of domestic hi-fi amps are no longer earthed, and are in fact designed to actively discourage the user from earthing them. So what gives?

Realising that I'd been away from this area for a while, and might perhaps have missed some important development in audio technology, I tried asking a few of the experts. Including famous names like Neville Thiele, of speaker design fame, and amplifier guru Cyril Murray. No, they said, there hadn't been any major developments. In fact as far as they were aware, it was still just as desirable to earth a high gain amplifier as it ever was.

How did they feel, then, about the fact that the majority of today's hi-fi amps were "double insulated" and not only not earthed, but not legally allowed to be earthed? The answer seemed to be that they hadn't really noticed, because it had all happened slowly and imperceptably — over quite a few years. But when it was pointed out and they gave it some thought, they weren't too happy about it at all.

That seemed to be the answer I got from everywhere. Except from the distributors of the equipment themselves, whose basic reaction was "It's all perfectly legal and safe — we've been doing it for years. What's the problem?"

Curiouser and curiouser, I thought. But there was still something else niggling away in the back of my mind.

When the concept of "double insulated" appliances first arose, quite a few years ago, I seem to recall that it was basically in connection with power tools like electric drills and saws. The kind of tools that are used on building sites, or in other hazardous and "heavy duty" situations.

The idea seemed to be that in this kind of situation, it was desirable to have particularly good insulation inside the tool itself, to ensure that it couldn't become a danger to the user. So as well as providing the usual *functional* insulation inside the tool's motor, the makers started providing a second layer of insulation enclosing the metal "frame" of the motor (and gearbox, or whatever). So any exposed metalwork of the tool, if there was any, was *doubly* insulated from the live wiring.

This ensured that even if the functional insulation inside the motor should break down, there was still the second layer of insulation to prevent any exposed metalwork from becoming live and endangering the user.

Fair enough. In itself, this was an entirely laudable development. But one of the things I've never been too clear about was that these double insulated tools were not supposed to be earthed. It's understandable that they didn't *need* to be earthed, at least as much as other tools and appliances, because of the additional insulation. But why did the safety authorities rule that they *should not* be earthed?

I can only assume that it arose from some kind of concern that if the earthing was via the usual 3-wire cord and 3-pin plug, the earth wire might somehow break off inside the plug, and touch the active pin — making the tool's exposed metalwork become very definitely alive and dangerous — despite the double insulation.

On the surface this seems fair enough. Wires can indeed break inside power plugs, and could perhaps move around and over the moulded-in barriers to touch the wrong pins. But of course they can do so just as easily or otherwise for "normally earthed" appliances — with results that are potentially just as fatal. That doesn't seem to have become an argument against earthing *any* appliances though, does it?

If we're dealing in long shots, there's

also the chance that *both layers* of insulation in a double insulated appliance could break down, and again render the outside metalwork potentially lethal. Without any obvious sign of danger, until you picked it up!

Of course if the outside metalwork happened to be earthed, a breakdown of both insulation layers would produce a blown fuse and make it clear that there was a fault.

I have to admit that it does seem rather more likely in a building site environment that an earth wire might break off inside the plug, than that both layers of insulation might fail. So I guess if I was forced to choose between double insulation and earthing, I'd probably plump for the double insulation.

All the same, if it really was me standing in the middle of a puddle of water using a power drill, I'd like the comforting reassurance of knowing that it was BOTH double insulated and properly earthed — even if this meant breaking the law. I'd rather be alive in clink than laid out as a virtuous corpse on a mortuary slab!

Anyway, as far as I can see, even for the original double insulated power tools, the logic behind the rule that they *must not* be earthed is rather dubious, to say the least. But when it comes to hi-fi amplifiers and similar equipment, things get even more hairy.

As I said earlier, the more I thought about the concept of double insulation, the less it seemed to make sense when applied to a typical hi-fi amplifier. After all, the mains wiring here goes simply to the primary winding of the power transformer, as in most other pieces of electronic equipment. So the first and functional layer of insulation would be the primary winding insulation — between primary and core/frame, and primary and secondaries. In other words, the usual moulded plastic bobbin, mylar tape, varnish and whatever.

But where would the second, protective layer of insulation go? To perform the original purpose of double insulation, it would really need to go in *two* places:

1. Between the transformer core/frame and the amplifier chassis, to prevent the chassis becoming live in the event of primary/core breakdown; and
2. Between the transformer core/frame and its secondaries, to prevent the amplifier circuitry itself from becoming live in the event of primary/secondary breakdown.

The second of these might seem a bit fatuous, but in theory it's just as important as the first. This is because by its very nature, a domestic hi-fi amplifier's circuitry must be directly connected to exposed metalwork: speaker connectors, RCA input connectors and so on. So if there were a primary-secondary breakdown, this exposed metalwork would inevitably become alive.

In reality both of these criteria can be met by using a transformer with totally separate bobbins for the primary and secondary windings, providing that the transformer's core/frame is also fully insulated from the chassis. But this is a fairly expensive approach, and from my inspection of various samples of modern "double insulated" hi-fi amps from different manufacturers, my impression was that none of them had actually done this.

Certainly some had separate primary and secondary bobbins, but few if any appeared to have insulation between the transformer core and chassis. So how could they be double insulated?

The answer to this came when I contacted Ron Profit, from the Standards Association of Australia (SAA). This is the national organisation delegated by the electrical safety authorities in each state to define and administer the various safety regulations.

Mr Profit explained that some time back, the definition of double insulation was changed. It no longer involves the concept of two distinct levels of insulation, but nowadays is defined instead in terms of an overall effective insulation rating. In fact, if the insulation between mains wiring and exposed metalwork will withstand 3750 volts RMS for a prescribed period of time, without breakdown, the appliance concerned is effectively double insulated.

So today's "double insulation" is not really the same as the original definition, but I guess even a single layer of insulation capable of withstanding 3750V must offer a pretty high degree of protection.

Having at least cleared this up, and while I had Mr Profit on the 'phone, I took the opportunity of sounding him out about the law that supposedly says you *mustn't earth* double insulated appliances. Was that indeed the case?

Yes, it was quite true, he confirmed. Double insulated appliances must be provided with a 2-wire cable and 2-pin plug, and must not be earthed. It's all there in SAA Regulation 3250, 1982, Section 5.2.

But when I asked *why*, he couldn't answer. To the best of his memory, it had been decided many years ago, by some committee whose members had probably long since retired. Exactly what rationale they used to make the decision against earthing was probably anyone's guess, nowadays!

So there you have it, at least from the SAA's point of view. Providing an amplifier or any other appliance has insulation capable of withstanding 3750V, it's "totally safe" as a double insulated appliance. It can be given the "concentric squares" label and fitted with a 2-wire cord and 2-pin plug. And if this is done, it cannot legally be earthed.

Frankly I for one am still not convinced about the safety angle, particularly when it comes to the prohibition against earthing. But I get the feeling I'm flogging a dead horse. So let's drop that for the present, and turn to the matter of amplifier performance.

Let's think for a moment about what happens when a piece of electronic equipment, powered from the mains via the usual stepdown/isolation transform-

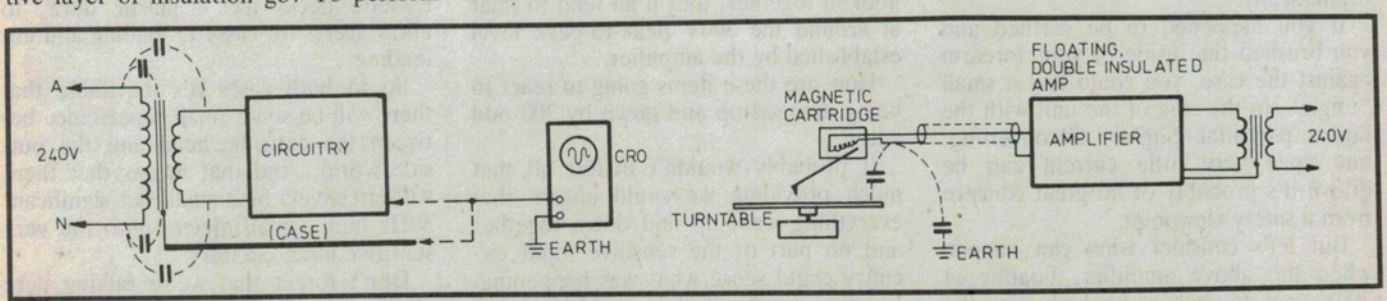


Fig.1 (left): Stray capacitance in the power transformer causes an unearthed double-insulated amplifier to "float" at up to hundreds of volts with respect to earth. Fig.2 (right): this can induce hum via the pickup cartridge wiring, for example.

er, is double insulated.

Instead of being electrically "tied down" to the same potential as virtually all of the large objects around — including the largest of the lot, the earth itself — the chassis and circuitry are left "floating". What this means is that the potential they adopt becomes determined by whatever nearby potentials may be coupled to them via mutual coupling impedances.

In most cases, the dominant potential will be that of the 240V mains wiring, coupled in mainly via the stray capacitances between the transformer primary, its frame and the secondary winding(s). So we have an AC potential of hundreds of volts, coupled to the chassis and circuitry via significant capacitance.

What happens is that the complete metal chassis and circuitry adopts a nett AC potential somewhere between mains active and neutral. In other words, they will wobble up and down with respect to true earth, by an AC voltage somewhere between 678 volts peak-to-peak (240V RMS) and zero.

Find this hard to believe? It's absolutely true. I carried out measurements on a couple of typical double-insulated hi-fi amplifiers, using both a DVM and a CRO with 10:1 high impedance divider probe. In one case the DVM read 32.8V RMS, and the CRO showed 175V peak to peak; in the other case the DVM read 88.9V and the CRO showed 305V peak to peak.

In both cases these were the voltages of the chassis/metal case and circuitry, measured with respect to mains earth. In neither case was there any difference between the case and the circuit potentials.

Of course these voltages are at a high impedance level, due to the stray capacitance effectively in series with the "generator". So if you try to draw any significant current, the voltage drops dramatically.

If you happened to be earthed and you brushed the inside of your forearm against the case, you could feel a small "tingle", in the case of the unit with the higher potential. Slightly disconcerting, but since very little current can be drawn it's probably of no great concern from a safety viewpoint.

But let's consider what can happen when the above amplifier, floating at 300V peak-to-peak, is hooked up to the usual array of companion equipment: a record turntable with magnetic pickup cartridge, a cassette deck and an AM/FM tuner.

These are all likely to be double insulated too, but typically with smaller power transformers and a higher "floating" impedance. So when they're all hooked together, they'll all tend to float at around the 300V peak-to-peak level established by the amplifier.

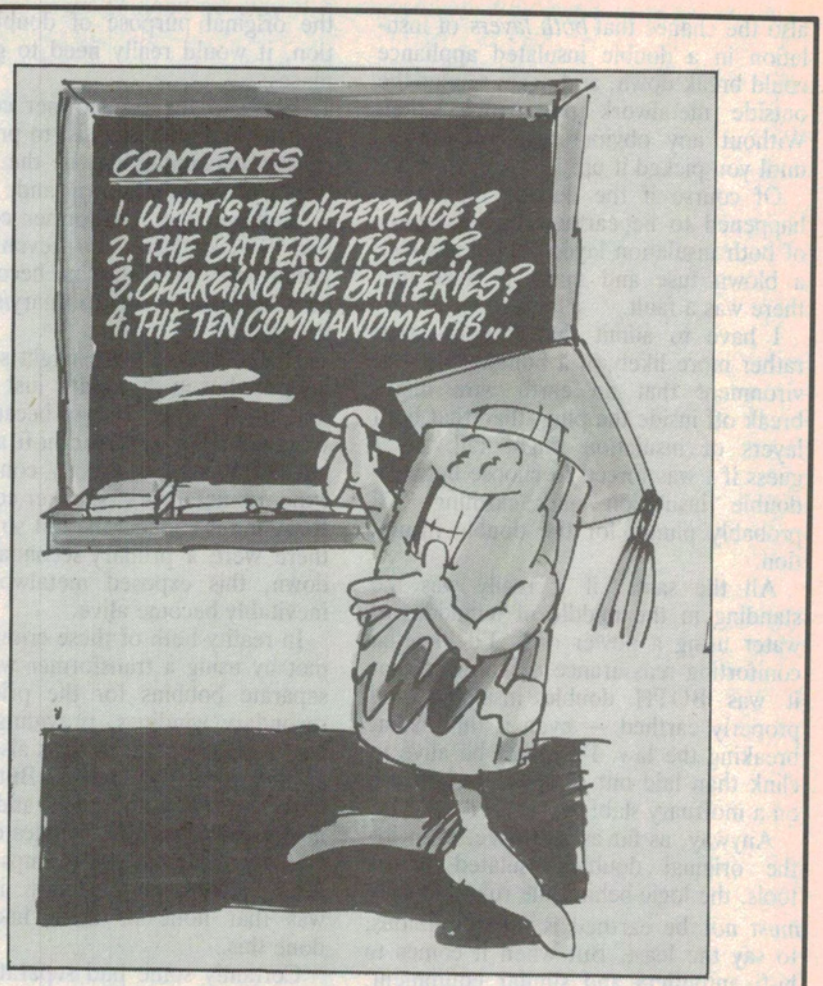
How are these items going to react to being dragged up and down by 300 odd volts?

It probably wouldn't matter all that much providing we could ensure that everything went up and down together and no part of the sensitive input circuitry could sense what was happening. In other words, if there were no stray capacitance to the "real" earth, from things like the pickup cartridge coils and leads, or the cassette deck's tape heads.

Unfortunately in practice this is virtually impossible to achieve. Most pickup cartridges are at least partly made of plastic, and most headshells are open at the bottom. Similarly, the front of most cassette decks has a plastic door, to allow access for cassette loading and unloading.

So in both cases it's inevitable that there will be some small capacitance between the cartridge/head and the outside world. And that means that there will effectively be a small but significant 50Hz hum signal injected into the very sensitive input circuitry.

Don't forget that we're talking here about parts of the overall audio system working at a fairly high impedance, and at normal signal levels of only a couple



Shortly after our January issue went to press with the Forum column on NiCad batteries, news arrived of a 24-page full colour booklet on the subject which has just been released by Arlec. Called "Rechargeable Batteries — Answers to the Most Asked Questions", it is said to provide easy to understand and not-too-technical explanations for both the consumer and salesperson. Chapters cover the differences between rechargeable and disposable cells, how NiCads work, charging and correct battery care. Copies are apparently available from Arlec dealers, or from Arlec itself at 30-32 Lexton Road, Box Hill 3128.

of millivolts, and followed by amplification of around 20,000 times. This is at mid frequencies; in both cases the equalisation characteristic is such that there will be even higher gains at lower frequencies, like 50Hz.

With the complete amplifier system swinging up and down by 300V p-p, it's not going to take much stray capacitance at the input to generate quite noticeable hum.

In practice that seems to be what happens. In some cases the hum can be quite intolerable, particularly via the pickup cartridge. Presumably this will depend on whether the turntable metalwork happens to be tied back to the "earthy" side of the pickup leads, or not — and if not, upon the floating potential adopted by the turntable (relative to that of the rest of the system).

We've certainly found evidence of this kind of problem ourselves, when we've been testing various double insulated amplifiers sent to us for review. Even "on their own", without being hooked up to a magnetic pickup or cassette deck, and with the inputs carefully terminated, we generally find there's quite an improvement in the measured signal to noise/hum ratio if the amplifier is earthed.

If you try hooking up a system to a TV set, to feed the TV sound via the hi-fi, things can get even more complicated. Many modern TV sets are also double insulated, so they too can introduce a further source of "floating" potential — possibly with significant harmonic and high frequency content due to the switch-mode power supply.

It's all very unsatisfactory. I've been hearing of people who've been so troubled by the hum that they've taken an amplifier back to the hi-fi store, thinking it must be faulty. Needless to say the store usually tries it out with the rest of their system (which is often quietly earthed somewhere, I suspect), and proclaims it "perfectly OK". The poor customer is generally sent home with it, and advised to have their house wiring checked out because it "must be faulty". Which is basically quite misleading, because the wiring probably isn't faulty at all. It certainly doesn't have to be, to produce the effect.

What's to be done? In the short term, I'd suggest to anyone who experiences hum trouble that they simply try earthing the system somewhere — either to mains earth, or better still to a water pipe. Technically you'll be breaking the law, of course, but I can't see that it'll do any great harm. In any case, the law concerned is virtually unenforceable — as well as being based on rather dubious and debateable logic.

There should only be a single earth, of course, to prevent the formation of an earth loop (which will generate more hum again, but another way!). I'd suggest it be connected to the amplifier, *or* to the turntable metalwork — whichever gives the lowest hum level. But not to both . . .

In the longer term, I'd suggest to the IREE Audio Group, hi-fi enthusiasts and anyone else concerned with the *performance* of domestic audio systems, as well as with their safety, that they apply pressure to the SAA and the various state authorities to have this whole business of double insulation re-examined.

Fairly obviously the concept is not really appropriate in the context of hi-fi systems, which are rarely used on building sites by chippies standing in the middle of puddles, or at the end of long extension cords with dubious earth wires. To insist that they must be treated as if they were is surely quite illogical, especially since it prejudices performance.

The sooner we tidy up this rather crazy situation, the better. EA