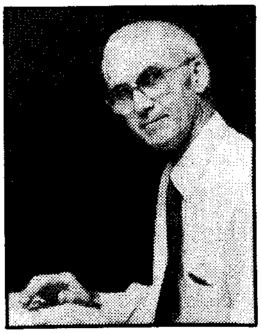
FORUM

Conducted by Jim Rowe



Does a "tingle" mean your appliance is dangerous?

In the old days of earthed electrical appliances, a "tingle" when you touched them was a warning that something was seriously amiss and the appliance concerned was likely to be dangerous. But nowadays, it isn't necessarily so – and if you're not careful, even measurements with a meter can be quite misleading.

Let's say your wife or mum is doing the washing up in the kitchen, and watching *Days of Our Lives* or whatever on the portable TV nearby. When it ends, she reaches over to change channels – and receives a rather frightening "tingle". Not a shock, so no actual damage is done, but a bit worrying all the same. So very wisely she wipes her hands, turns off the TV at the power point and unplugs it, just to make sure. Then she waits until you get home, and tells you what happened. Is the TV faulty and dangerous?

You're not sure, but a tingle is certainly a bit worrying – and you wouldn't want her to be in any danger, of course. So straight away you get out your nice new digital multimeter and switch it to the highest AC volts range. Then you plug the TV back in, switch it on (first at the set and then at the power point) and gingerly measure between the channel-change buttons and the stainless steel sink.

Good grief – the meter reads over 100 volts! No wonder your good lady received that tingle. It must be faulty and dangerous, after all. It's one of those double-insulated appliances too, with only a two wire cord and 2-pin plug, so there isn't even a protective earth. It's a wonder she wasn't killed...

So you take it halfway across town to the manufacturer's service department, and ask them to examine it carefully for a suspected dangerous leakage. But when you go to collect it again a couple of weeks later (well, say three weeks later), they couldn't find anything wrong with it. Supposedly it's perfectly OK, and quite safe. All you're up for is the $45 minimum service fee.

Hmmm. When you take it home again and try measuring between the TV channel buttons and the kitchen sink, the meter still reads more than 100 volts. Who's kidding whom – didn't those turkeys in the service department do *anything* for that 45 bucks? Is the blanky thing dangerous or not? It's all very disturbing.

Well, have I got your attention? I hope so, because electrical safety is an important subject and something we electronics types are often expected to know about and offer responsible advice on. We of all people should be clear about how to determine if an appliance is safe or not, without any confusion.

By the way, in case you're wondering the above story didn't actually happen – I made it up, just to kick off the discussion. But it's a scenario that certainly *could* happen nowadays, given the prevalence of double-insulated appliances (including TV sets) and digital multimeters. In fact a very similar chain of events did occur recently, as was explained to me by the safety approvals manager of one of the large manufacturers.

What actually happened was that a lady did get a tingle from her portable TV set, in a similar situation. She promptly called the local office of the electricity authority, and a safety inspector was sent out to investigate. When he arrived and used a digital multimeter to measure the voltage between the TV set controls and the kitchen taps, he did indeed get a reading of well over 100 volts – and promptly declared the TV unsafe.

The TV set was almost brand new, as it happened, so the lady's husband not surprisingly took it back to the manufacturer's service department. Here he demanded to see the manager, and asked why the company was selling sets that were unsafe. It was then that my friend the safety approvals manager was brought into the picture, to test the set and see if it was indeed faulty and dangerous.

Now the gentleman concerned is very experienced in this area, and is in fact a member of various SAA committees to do with electrical safety. So he promptly carried out the official tests, to see if there was anything wrong.

The verdict? There was in fact nothing wrong with the set at all. It easily met all of the prescribed tests for electrical safety, and was quite incapable of delivering a dangerous current or shock.

In other words, the county council's safety inspector had actually been quite WRONG in declaring it unsafe. Even though it could indeed deliver an undeniable "tingle" in the right circumstances (as the lady had found), and would also produce a leakage voltage of well over 100V as read by a digital multimeter.

So what's the explanation? Let's look into it a bit deeper.

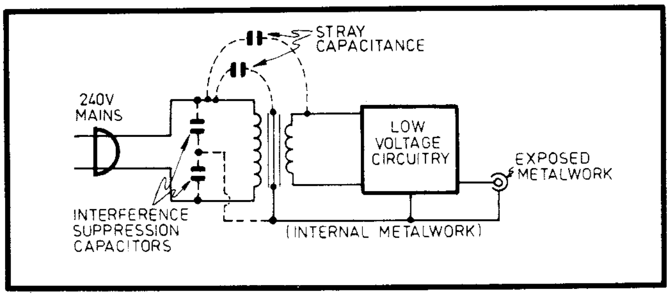
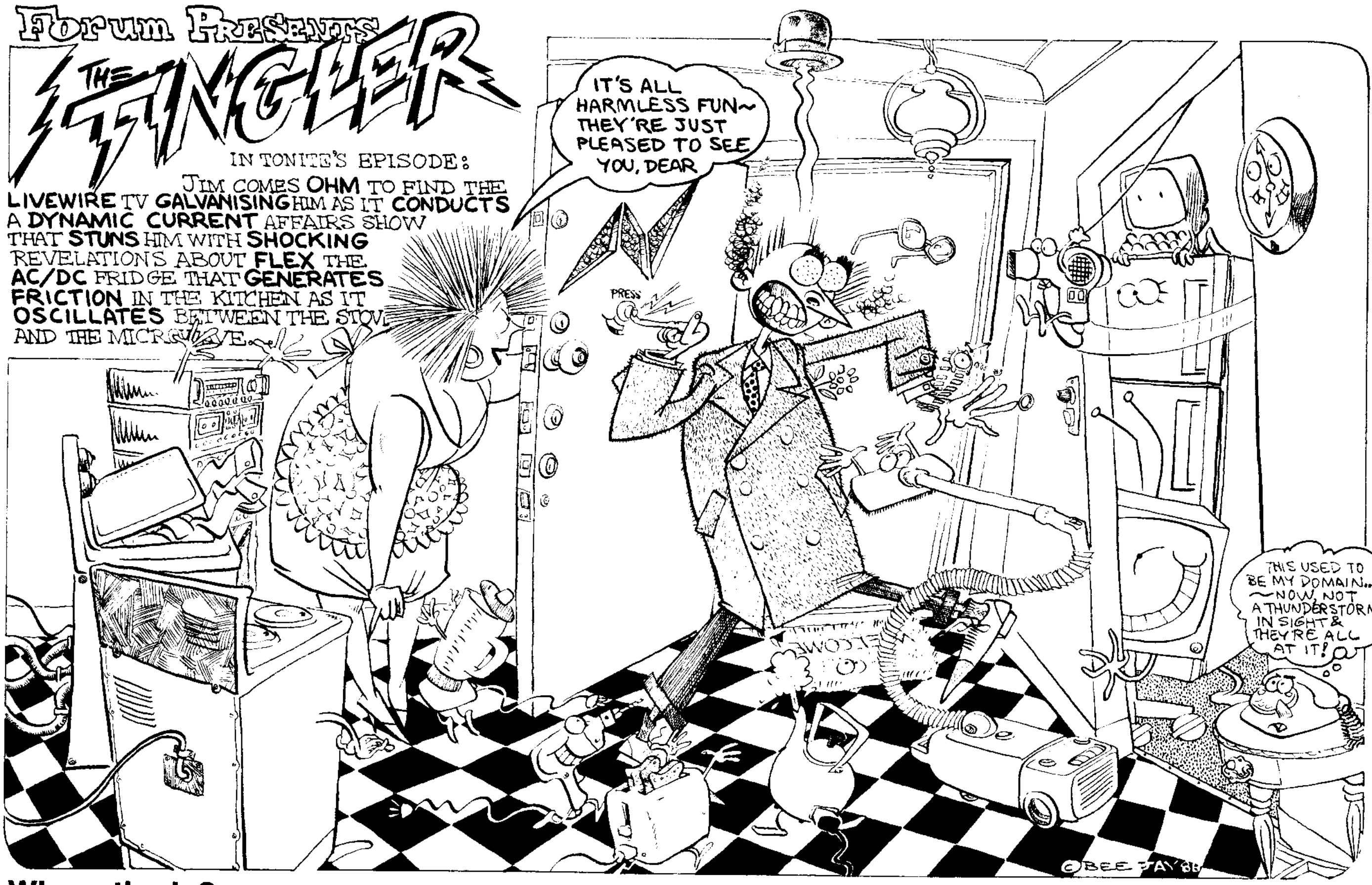


Fig.1: Due to things like stray capacitance, the exposed metalwork of a double insulated appliance can easily produce a "tingle".



Why a tingle?

Inside almost all electronic appliances powered from the mains is some kind of power transformer. This is either connected directly to the 240V power line, or indirectly via a switching power supply circuit. The basic purpose of the transformer is twofold: (a) to change the mains voltage into whatever voltage or voltages are better suited for powering the appliance circuitry, and (b) to isolate the circuitry as a whole from dangerous mains potential.

In general you can visualise the transformer's primary winding side as floating at the full potential of the active mains lead. Certainly in the simplest case this will be true for at least one side of the winding. With a switching supply the situation is rather more complex, but the basic idea isn't too much different.

Now the secondary winding(s) are normally separated from this primary winding by a number of layers and types of insulation, providing a high degree of *conductive* isolation. So the straight ohmic conduction path between the two will have a very high resistance indeed – typically from many tens to hundreds of megohms.

The internal circuitry of the equipment will generally be directly connected to the secondary winding(s), and quite often any exposed metalwork will be also. This means that these too will only be connected to the mains via the extremely high resistance of the insulation layers, as least from the point of view of straightforward ohmic conduction.

If this were the only way that current could flow, there would probably be no chance of getting even a faintly noticeable "tingle" from a normal appliance with undamaged insulation. Ohm's law tells us that with a series resistive path of say 100 megohms, the maximum current that could flow with 240V applied would be only 2.4 microamps. This is well below the level that will produce even a tingle – unless perhaps you have it flowing between electrodes connected to your tongue, or some other highly sensitive part of your anatomy!

But of course ohmic conduction *isn't* the only way that current can flow. Where alternating current and voltage are involved, there's also reactive "conduction" – the AC current that flows through things like capacitors and inductors, as a result of their reactance.

In this case there is often quite a significant capacitive path between the mains wiring entering the appliance and the circuitry/metalwork on the "other side" of the power transformer. As shown in Fig.1, this can often consist of two main items. One of these is the stray capacitance between the mains wiring and transformer primary, on one side, and the transformer core, secondary windings, appliance circuitry and metalwork on the other. This capacitive path is always present in all equipment, but its value varies between a few tens and a couple of hundred picofarads (pF).

The other item is any discrete interference suppression capacitors which may be deliberately connected between the mains wiring and the equipment metalwork. While larger in value than the stray capacitance, these are generally only found on equipment that is designed to be used with a mains safety earth. In fact they mustn't be fitted to double-insulated equipment, because of the safety risk if they should break down.

Let's forget these interference suppression capacitors for the purpose of the present discussion, then, on the basis that they're normally only going to be found on earthed equipment – and you can't get a tingle from such equipment if it *is* properly earthed.

So we're left with the stray capacitance, of around (say) 100pF. At the 50Hz mains frequency this has a capacitive reactance of about 32 megohms – rather less than the resistive leakage

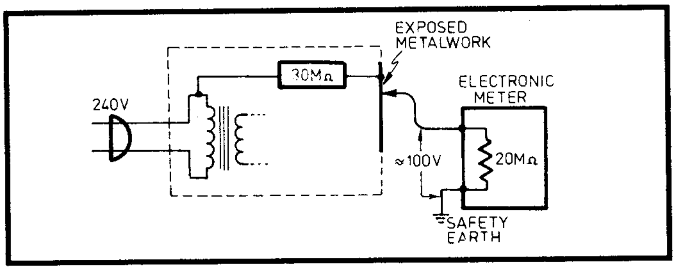


Fig.2: Measuring the leakage with a high impedance electronic meter tends to produce a high voltage reading.

path we've already considered, although still quite high.

The thing is that when both the resistive and capacitive leakages are taken into account, the nett leakage impedance will obviously be lower than either. So with 240V AC applied, there can be the potential to supply rather more current – say a few tens of microamps. And this is where the tingle can come from.

But is it safe?

Now comes the crucial question. A current of this order may be able to give you a noticeable little tingle, but is it dangerous?

Broadly speaking, the answer seems to be no. At least, it isn't if the current is applied to you in the usual external ways. It might be dangerous if passed directly through the wrong part of your heart muscle during an operation, perhaps, but otherwise there's general agreement that it would not cause you any injury.

In fact the Standards Association of Australia specifies that a current of up to 700 microamps (0.7mA) peak is deemed safe for AC, and up to 2mA for DC. However the relevant SAA standard notes that for some conditions – especially where there is a high humidity – it may be necessary to ensure that leakage current levels are kept below 0.3mA peak (300uA), to reduce *discomfort*. In other words, to minimise the "tingle current".

OK then, so getting a tingle doesn't in itself necessarily mean that the equipment concerned is dangerous. It *could* be quite safe – but how can you be sure? After all, an appliance that is faulty will also tend to give you a tingle, and in this case the situation could be potentially lethal. It would obviously be very foolish to become blase about tingles in general.

Testing it

Needless to say, the sensible thing to do is *measure* the leakage, to see if it is safely below the danger level.

But what's wrong with measuring the voltage between the appliance's exposed metalwork and ground, with one of those nice new digital multimeters – like our hapless county council inspector? The problem here is that the test is quite unrealistic.

Modern electronic digital multimeters (or electronic analog multimeters, for that matter) have a very high input impedance – typically 20 megohms. This is fine for making most normal measurements in sensitive electronic circuits, without disturbing them and loading them down. But in this case it doesn't show what happens to the voltage between the appliance and ground when the leakage circuit has to deliver current into the kind of load we're most concerned about: a human body.

If the leakage path has an impedance of say 30-odd megohms, for example, the effect of connecting the digital multimeter's 20MΩ of input impedance between metalwork and earth will be quite modest (Fig.2). The total circuit impedance connected across the 240V will be 50 megohms, which will draw only 4.8 microamps, and the proportion of mains voltage across the meter will be about 2/5 of 240V, or around 100V RMS. And this will be the reading shown on the meter – apparently quite high.

Even if the appliance was faulty and the leakage path had fallen to only 10kΩ, the total circuit impedance would still be over 20MΩ and the current still only 12uA. The meter would then read almost 240V, to be sure, but superficially this is only a bit over double the reading with an appliance that is quite safe.

The situation would be quite different if you or I were connected – particularly if we have wet or sweaty skin, to achieve a relatively "good" contact. Our effective load resistance would be below 50kΩ, bringing the total circuit resistance down much closer to that of the leakage path by itself. And the current that flows would be determined not so much by us, but by the leakage impedance.

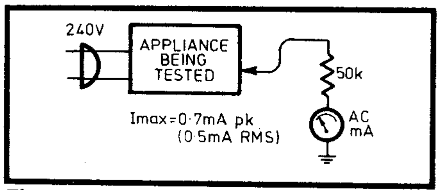


Fig.3: With a 50k load, only 0.7mA peak current should flow.

So if the appliance is safe, with a leakage impedance in the tens of megohms, only a few tens of microamps will flow – and because most of the voltage will be dropped across the leakage impedance, very little will appear across our body: a few volts at the most.

But of course if the appliance is faulty, with a leakage impedance much lower that it should be, a lot more current will be able to flow. And proportionally less voltage will be dropped across the leakage impedance, leaving much more across us...

To find out whether an appliance is dangerous or not, then, it's important to measure the leakage current or voltage in a realistic fashion. In other words, by measuring in a way where the loading at least approximates that of a human body.

The SAA standard suggests that a suitable load impedance is in fact 50kΩ . So the SAA's test of appliance safety involves measuring the leakage *current* when such a load is connected (between the exposed metalwork and a reference or "safety" earth. And as noted earlier, the current in this situation must not exceed 0.7mA peak (0.5mA RMS) for the appliance to be deemed safe.

So the way our county council safety inspector *should* have measured the suspect appliance is shown in Fig.3. And this is the way *we* should make the measurement too, if we want to check out an appliance that has delivered a tingle or is otherwise under suspicion.

What if you don't have a multimeter which can measure small AC current levels? Then you can use the slightly modified technique of Fig.4, which relies on measurement of the AC voltage drop across the 50kΩ load resistor. Ohm's law tells us that this will have a voltage drop of 35V peak or 25V RMS for the prescribed maximum current level – so any voltage readings below this level are OK.

The critical point is that you need to use a 50kΩ load resistor, to provide a realistic testing situation. And ideally the resistor should be non-inductive, to prevent inductive reactance from complicating the situation.

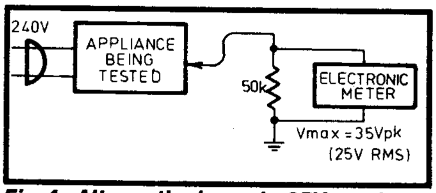


Fig.4: Alternatively, only 35V peak voltage should appear across 50k.

Providing you use this load resistor, it doesn't matter much whether you measure the leakage current as such, or the voltage drop created across the load resistor. Either way, you'll get an unambiguous indication of whether the appliance really is safe or not.

Summarising then, you can indeed get a "tingle" from double insulated appliances – even when they're quite safe. But don't take any chances: if someone does get a tingle, check out the offending appliance carefully. Just make sure you test it correctly though, with that 50kΩ load resistor.

That's about it for this month. Next month I hope to look at the rather weird subject of "oxygen-free" copper, and its use in speaker cables and other audio components. I hope you'll join me.