Much Ado About Nothing

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1. Precision in Audio

"O, what men dare do! What men may do!
What men daily do, not knowing what they do!"

Much Ado About Nothing (IV, i, 19-21)

So there we were, kicking back as England #Euro2016 had just scraped through to the knockout stages (albeit in 2nd place) and reading the FT, covering the reaction to all this In/Out Referendum malarkey #Brexitandchill.

Suddenly several private messages/emails disturb our peace and chillout. It seems at Computer Audiophile and other places, some readers noticed some threads about some measurements: '*Dear AMR/iFi, please address the measurements made by this person and look at the measurements made of the iPOWER by that other person.*'

Frankly, we really don't see what all the fuss is about as it is only one person taking measurements and another taking another set of measurements. One somewhat tallied with the published iPOWER numbers while the other didn't. No big deal. Neither looked quite right, but in different ways.

The Art of (Measuring) Noise

Those who studied 'Messtechnik' (lit. the technique of performing measurements) during the ages of needle meters and before digital systems, FFT analysers etc. don't lose sleep because X measured Y. They know there is a measurement error and it just needs to be tracked down.

The actual technical term for measurement results that show things that are not really there in reality is 'Instrument Ghost.'

No, it does not suggest actual demonic possession of an electronic component where it starts to levitate and spin 360 degrees whilst vomiting furiously.

No, it actually refers to something far more mundane: *what is seen in the actual test results is not real, but a trick of lights; interference in the test system* etc.

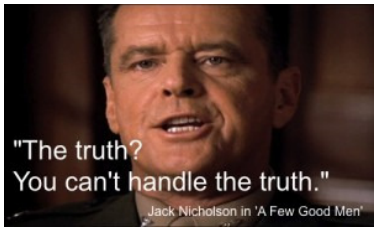
Synopsis: *With measurements of any sort, one needs to know the limits and pitfalls otherwise 'false positive' results can deceive.*

AP changed the game or did it?

Back in what some might now view like the Middle Ages barely removed from the times of the Bard (think c. 1985), making electronic measurements was a very serious craft. Many a test were far from straight forward. Carrying out a comprehensive performance test on an amplifier could and would occupy days on end. If one was unfortunate to find an Instrument Ghost, one could lose weeks of work chasing a non-existent 'problem.'

Circa 1985, enter Audio Precision and their System One, a computer-based audio test system. The System One combined an integrated generator + analyzer + connected PC to fully automate test procedures. This setup allowed a radically different visual presentation of results and doing so *rapidly*. Over the years, Audio Precision[1] has become the de facto standard for Audio Testing.

Does the fact that it is the industry standard for audio testing mean that an Audio Precision system is truly precise and will never show 'instrument ghosts?'



Of course not. Under the cover sits the same sort of circuitry we had in the old, hard to use analyser; it is just that the use of the computer to control the test system and easy user interface simply hides the great complexity that is still there. Numerous opportunities for 'instrument ghosts' *still exist*.

Having used Audio Precision for the better part of over a decade here at AMR/iFi, we respectfully believe we have a fairly good grasp of what the limitations are and crucially, can tell if what we see is a real or perceived problem a.k.a. 'instrument ghost.'

Synopsis: *The Audio Precision is just as fallible today as with earlier generation measurement tools. One STILL needs to know, be aware of the limits and pitfalls otherwise the results mean little.*

Next time, Part 2: Instrument Ghostbusting…

1 The System One was soon followed by the System Two and now the System X (APX) series.

2. Instrument Ghostbusting

One look at the contentious test results we have been asked to look into by our readers instantly suggested that indeed what we were seeing was a distinct case of severe instrument ghosts. Holy water won't work in this case.

We commend those who have a stab at measurements. It is always easy to thrash the keyboard to within an inch of its life on forums about this person or that person but life is too short. Let's all just chill and instead, share our knowledge/experiences;

One set of test results done using an older Audio Precision System was a prime example of one of the AP's main limitations but unfortunately blame was laid at the door of the iFi product.

Somewhat worrying was some of the discussions showed people comparing the results of:

i. Two very different tests
ii. Tests done by different people
iii. Using very different test gear
iv. …and with different scaling
v. …and with very different outcomes.

The poster then simply declaring blithely that the second set of test results confirmed the first, whereas in fact they clearly repudiated the first set of results and showed them to be instrument ghosts.

It seems that few today know those arcane disciplines of proper testing and how to spot Instrument Ghosts. They may or may not even know of the existence of Instrument Ghosts. Many try their utmost to make technical measurements but are sadly undone by an error here and an error there.

"If there's something weird and it don't look good, who you gonna call ***Ghostbusters!****"*

Okay, we can hear you ask: *"What is the problem with the Audio Precision System then?*

Answer: *Lack of galvanic isolation AND multiple earth connections.*

Measuring Noise requires full Galvanic Isolation

In order to avoid ground loops when testing audio gear the AP features a galvanically-isolated output from the signal generator (which is fairly easy to do), but the Inputs are ground referenced and ground is linked to Earth. And the AP is linked to the Host PC WITHOUT Isolation. The PC usually has its own earth. This arrangement makes the AP system susceptible to ground/earth/mains-related noise.

That is not a problem per se for most tests; it only effects cases where we want to actually measure system noise and fairly low levels of this noise at that! Of course these issues are known and it is often necessary to experiment with ground and removing grounds; using isolation transformers to power gear under test etc.

At AMR/iFi we have a fairly complex setup with multiple isolation transformers separating AP2, Host PC and the Audio device being tested. Overall this setup massively reduced the tendency for instrument ghosts but took an age to develop and then extra time and a chunky budget to arrive at a completely safe, reliable package. Any AP2 and PC just plugged into common mains does MUCH worse. We've been there, done that. Got the t-shirt and the key ring.

What we will do in this system, we shall see what the AP2 can do under those conditions and if we can provoke major noise problems WITHOUT touching the actual audio signal at all; but just by messing with grounds.

Synopsis: *Care and attention to setup the optimal environment is needed to rule out spurious noise sources. Even the expensive AP does not have FULL galvanic-isolation and is hampered by multiple earth connections.*

One must address these before commencing any sort of precise noise measurements.

Next time, 3. GSI: Ground Scene Investigation…

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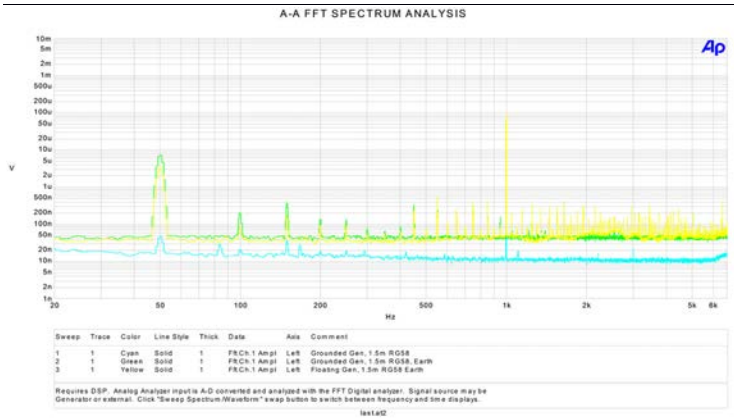
So, could it be that the very expensive Audio Precision system is susceptible to Instrument Ghosts simply by getting connections wrong?

Please bear with us as we run through a forensic examination of the 'crime scene.'

Exhibit 1 – Ground Loop to Major Tom
For our first exhibit, we set the AP2 to output a 0.1mV (0.0001V) signal (also used in following measurements) and used a good quality cable (RG-58 plenum with BNC connectors) to link the AP2 output to the input.

As seen in the cyan trace below, this shows a FFT noisefloor at around 10-20nV (that is 0.00000001V to 0.00000002V) with no noise/distortion spikes higher than 50nV (0.00000005V). Compared to a nominal 2V DAC output we are looking at -152dBFS! Sterling performance. This is what one buys for five figures.



But wait, what if we take a clip lead, attach a crocodile clip onto the ground of our BNC Plug and connect the other side to the mains earth?

This would be like having a laptop feeding a USB DAC where the laptop power brick has a 3-pin mains plug?

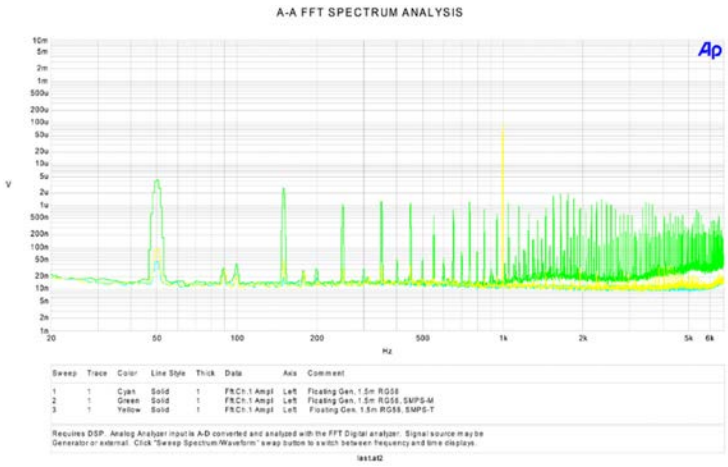
Note, we have changed nothing whatsoever in the signal path. Our 0.0001V signal still comes from the AP2 generator via 1.5m of high grade coaxial cables. All we have done is simply added an earth wire…

This calls for an F-Bomb. $%#@! What is that?

As the yellow trace shows, our simple wire between ground and earth has added distortion at multiples of the 50Hz mains frequency with 50Hz being especially awful. It sits at around 7uV (0.000007V) instead of 50nV (0.00000005V), this is over 140 times more noise. The overall noise floor has risen nearly 5 times as well. Even isolating the generator output as shown in the **green** trace only drops the 50Hz noise slightly to 5uV, still 100 times worse than without that pernicious earth wire!

Exhibit 2 – Harmonic Spray smells fishy

For our second exhibit we replace the wire to earth with a generic SMPS (we used one included with another manufacturer's USB Repeater product as it was lying around) plugged straight into mains. We just connect the power supply DC plug ground instead of our Earth. This is still totally separate from the signal! We have retained the cyan trace from before for reference. Will we get a major dose of noise?



As the **green** trace above shows, we sure do, not just 50Hz but we get an extended spray of harmonics all the way to the frequency limit.

The spiky noise / distortion components push the overall background noise up to around 25uV RMS noise, according to the AP2! Yup, that is 500 times more noise than the reference test and we have not touched the signal AT ALL!

Signs of 'Para-electrical' activity

There is one more key 'strange' factor in the green trace that is noteworthy:

i. Peaks at 50Hz (mains frequency) and at 150Hz (3rd harmonic) and at 250/350/450Hz and so on….
ii. but at 100/200/300Hz and so on, there is very little noise???

No EMF meter needed here; if it looks like one, walks like one, we would say this is a sure indicator of 'para-electrical' activity by instrument ghosts!

Applying common 'electrical' sense

- All power supplies work on rectified mains. If the noise originated with the power-supply – we would expect to see a lot of noise at 100/200/300Hz etc. but very little at 50/150/250/350Hz etc.
- Given it is the other way around we know reliably we are looking not at power-supply noise, but at 'instrument ghosts.' Now that we know this, can we bust these ghosts in any way?

BTT – Balanced Transformer Technology
In the FFT graph there is also a yellow trace. This shows only a little more noise than the reference test! This is actually exactly the same setup with the SMPS ground to the signal cable ground, but with one crucial difference. The SMPS is no longer plugged into the mains, but instead into a balanced isolation transformer. An inexpensive, off the shelf unit costing £25 was used.

The result is impressive. Noise is now around -146dBFS relative to a common DAC output. We can actually do something here people!

So, it would seem if we really want to measure noise with an AP, we need to take not some, but a lot of care and a little lovin.

Rehash to those in the know
This not 'new news' to those skilled in the electronic arts, but challenging to those who lack the necessary background and experience. There is no substitute for an EE degree AND decades of practice.

Further, measuring noise below 10uV (0.00001V) using common gear requires extreme care. We know of many setups that are useless below 1mV (0.001V) because of inherent and unresolved (and oft unrecognised) problems.

Synopsis: *The limitations of test gear are never covered in the user manual and it takes knowledge + experience to spot 'false positive' results. Care, care and more setup care is even more crucial than having expensive equipment to obtain the true, accurate and informed measurements.*

Next time, Part 4: Measuring the iPOWER down to 1uV noisefloor…

4. Let's measure the iPOWER down to 1uV

Three outs in a week

It has been a turbulent few days of 'outs' for the UK - out of the EU, out of Euro 2016 and now the 3rd strike is 'out': measurements of the iPower.

We're the first to admit the 3rd is inconsequential. We hope everyone understands the lightheartedness of the 'measurements' situation. Let's all sit back, enjoy the tunes and #brexitandchill.

So without further 'ado' (we couldn't resist) let's out the iPower.

The 52%:48% question

The one question we have not yet answered in all this evaluation of how instrument ghosts can FUBAR AP2 measurements:

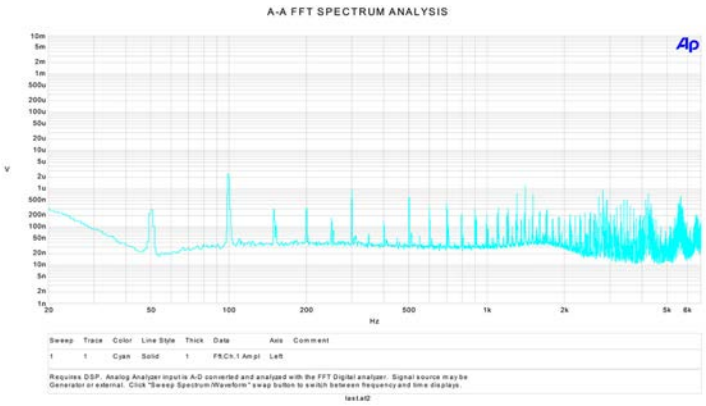
'By Jove, we don't want to know all of this – we only want to know how does the iPower REALLY measure?'

Had we not shed light on and validated our test setup and HOW we ensure accurately, measurable low-noise levels, we might just have plugged things together and gotten the green trace from the second graph in section 3. That would actually not have been the noise of the iPower but the noise of poor ground management and of using test gear with a known sensitivity to noise.

Measuring the iPOWER

Now for the part you have all been waiting for, let us measure the iPOWER.

The lowest ground noise setup was used with a 9V iPower delivering 750mA current (into a 12 Ohm/50W resistor) and the signal on the +/- side of the resistor was fed into the AP2 unbalanced input.



The FFT noisefloor is around three times that of the AP2 itself at around 30nV (0.00000003V). We can also see that, as it should be for a power-supply, 100Hz is the highest peak at 3uV (0.000003V). And other high peaks are at multiples of 100Hz (not 50Hz…).

The rest of the noise is all below the 1uV line and of course, in-line with the stated specification.

Conclusion

1. If you see much more noise than shown above 1uV in your measurements of an iPOWER and;

2. In particular, if 50Hz or 60Hz noise is much higher than 100/120Hz instead of being much lower, your setup is being 'haunted' by Instrument Ghosts.

Thank you for bearing with us. Refill please kind sir.

Find us on: and on https://twitter.com/ifi_audio

About iFi

iFi Audio, part of AGL, is headquartered in Southport, UK. And also owns the HiFi brand Abbingdon Music Research (AMR). AMR designs and manufacture high-end audio 'home-based' components. iFi Audio designs and manufactures portable and desktop 'ultra-fidelity' audio products. The combined in-house hardware and software development team enables AMR and iFi audio to bring to market advanced audio products.

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