AUDIO OUT

Product review

By Jake Rothman

Audio Out special – review of Peak LCR45

Most of us have a DMM that can accurately measure resistance – but what about capacitance, inductance and impedance? Jake Rothman reviews a flexible new impedance meter from Peak that meets this need.

Occasionally new test gear is launched that can really make one's life more productive. Sadly, often the opposite's the case, *but* the arrival of the Peak LCR45 (Fig.1) wiped many tedious and repetitive calculations from my life with the push of two little buttons. They've done the number crunching so I – and of course you – don't have to. I've always thought that being able to easily measure parameters brings the quantitative and empirical aspects of design closer together. Peak's little unit combines standard inductance (*L*) capacitance (*C*) resistance (*R*) and impedance (*Z*) measurements in a pocket-sized device.

Basic accuracy

I have a stash of military resistors and capacitors with very close 0.05% and 0.01% tolerances, see Fig.2. Checking these with the Peak showed them to read within these tolerances, which gave me confidence in the unit's basic accuracy. It was much better than my digital multimeters. The resistance agreed with my 5-digit DMM. The best inductors I have were only ±2%, but I know that Peak have 'Repair and Calibration Ltd' traceable calibration standards. The unit can even auto-null the *LRC* parameters of its own probes for accurate reading of low values.

Fig.1. The LCR45 impedance analyser and LCR meter. The attachable surface-mount tweezers are an optional extra

Autosetting

The LCR45 automatically detects the type of component being measured (*L*, *C* or *R*), using DC for resistors and a suitable frequency for reactive components (1kHz, 15kHz or 200kHz). Small values need high frequencies and audio parts normally use 1kHz. It is possible to de-select the auto function and make the unit stay in one mode. For audio work, mainly transformer testing, I set it to the 1kHz inductance mode. To be honest, it is a pig for a non-menu-oriented person to set this up, possibly because of a time-out set for a 20 year-old! (My 17 year-old son can reconfigure it very quickly) I took the lazy way out and now have two units in the lab, one on auto, the other set to '*L*' at 1kHz. Maybe an extra frequency select button is the solution, but the re-tooling cost would be prohibitive.

Impedance

For beginners, I say 'impedance is AC resistance', but that is not really true. It is more accurate to say it is the Pythagorean combination of DC resistance (the real part) and AC reactance (the complex or 'imaginary'

Fig.2. A simple task – measuring a 0.05% tolerance precision resistor

Fig.3. Using the LCR45 to measure the impedance of a loudspeaker. Note it is slightly below the specified 8Ω. This is a standard trick to boost the apparent sensitivity at the expense of increased current draw

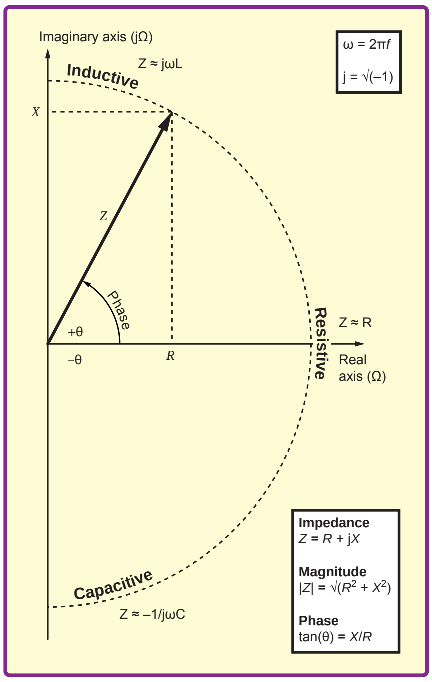

Fig.4. Argand diagram illustrating complex impedance

Fig.5a (top). Connecting a small radio frequency choke to the LCR45. Just before turn-on. Fig.5b. (bottom) Stepping through the measurement sequence on automatic with a small inductor. This shows the inductance, the DC resistance and the frequency at which the measurement was made

part) called the impedance magnitude. This is why some components, such as loudspeakers, are given an impedance value. A typical 8Ω speaker will have say, 6.3Ω of DC resistance due to the thin wire used in the voice coil and an inductance due to the winding on a magnetic core. Fig.3 shows a small Visaton 8Ω speaker measured on the Peak. Note that the impedance's magnitude and the phase are given. This is called 'polar form'. Speaker impedance is normally specified at 1kHz in the middle of the audio range and well away from the fundamental resonance, which causes an impedance peak.

Complex numbers

When dealing with impedances and reactances, pretty soon you bump into an area of mathematics called 'complex numbers'. An equipment review isn't the place for a maths lesson, but it is well worth explaining why they are used. If you are dealing with alternating

Fig.6. With each push of the 'enter' button, the unit goes onto the next measurement. Complex impedance is now displayed

Fig.7. Admittance – reciprocal of impedance

Fig.8. Impedance magnitude and phase

voltages and currents then to fully describe a signal you need to quantify the signal's frequency and magnitude (for example its peak value). However, that is not the full picture. You also need to describe a signal's phase. For example, the phase relationship between current and voltage. In a purely resistive circuit the current and voltage are exactly in phase – the voltage and current rise and fall together; but, as soon as you add some capacitance and/or inductance then this phase relationship changes, and this is where complex numbers become useful. Applying complex numbers let's you easily take account of not just frequency and magnitude, but also phase. When wielding 'complex numbers', engineers use the *j* operator to wind up mathematicians who like to use *i* to denote 'imaginary' numbers (more seriously, *j* is used to avoid confusion with *i* for current).

When quoting an impedance (Z) in complex form you will see a figure of the form $Z = R + jX$. The R represents the purely resistive part of the impedance and the X part is the purely reactive part. You can't just add these two components together because the X part is multiplied by *j*, the complex operator. Although tricky to use, complex notation is a useful mathematical tool to indicate the reactive and real parts of an impedance. The main advantage is that we can perform AC circuit analysis using simpler calculating techniques developed for DC. To have a tester that gives a direct readout for a component or network in complex form is unique at Peak's price.

'Complex numbers' do appear complex to many electronics students and they find AC theory dull. The Peak unit's instant readout (see Fig.6) removes this layer of abstraction, aiding the learning and prototyping process. I remember the same liberation occurring when we went from null bridges to digital multimeters. (I must talk to the university technician and get him to order some!) The proper printed manual supplied with the Peak illustrates complex impedance in a succinct 'Argand diagram', shown in Fig.4. The unit will also give admittance readings (see Fig.7) which are the reciprocal of impedance and useful for calculating components in parallel.

Testing common components

Inductors

A great deal of inductors are custom-made components having only a cryptic in-house ID number and many more are simply left unmarked. An inductance meter is a great help here. Also, one may have to wind one's own for say, Theremin loading coils, lightning detectors and switch-mode power supplies. Using the Peak I was horrified to see the discrepancies between data-sheet calculations for pot cores and the actual measurements; sometimes 50% out.

Since the unit gives simultaneous readings for inductance and DC resistance, it is ideal for checking loudspeaker passive crossover inductors, which are often air-cored with significant resistance. This must be taken into account with the design. The same is true with RF (radio frequency) components where the resistive losses determine the 'quality factor' or Q of resonant circuits. Fig.5 to Fig.8 show me stepping through the readings for an old radio frequency choke.

Capacitors

The LCR45 has a null function for cancelling the probe parasitic capacitance and it is capable of measuring very low capacitances, such as those between strips in a breadboard, down to about 0.5pF. Fig.9 shows the unit measuring a close tolerance polystyrene capacitor.

Fig.9. Measuring a 2% tolerance 100nF polystyrene capacitor

Resistors

One problem I have had with with wirewound resistors is parasitic inductance. The 0.22Ω source resistor shown in Fig.10 caused oscillation problems with some MOSFET power amplifiers I was designing. The inductance was 10 times higher than normal, which stopped the Zobel network from working. I found the cause to be the resistor manufacturer had used low-resistance copper wire instead of Nichrome, requiring many more turns for a given resistance. This resulted in higher inductance. A normal Welwyn vitreous wire-wound resistor is shown in Fig.11. If you need a near-zero inductance resistor then a film or composition resistor must be used (Fig.12).

Audio transformers

For anybody involved in transformer-coupled audio circuits, this tester is an essential piece of kit. For example, if you are building a Deacy amp (see *Germania* Part 3, *EPE* June 2015); a transformer-input moving-coil RIAA pre-amplifier (*EPE* Oct 2015); or a Neve microphone pre-amplifier, you can check your transformer impedances are right. I even used the unit to sort out an impedance problem with a 100V line-distributed loudspeaker system in a hotel which paid for the unit several times over. Here's some measurements I took from some common audio transformers:

- Eagle LT44 driver transformer loaded with 1kΩ across whole secondary, Z_{in} = 16.5k, primary inductance = 738mH
- LT700 output transformer with 3.3Ω load, Z_{in} = 1.1kΩ across whole primary, 38mH inductance (useful for calculating the bass roll-off point)
- LT726 output transformer with both 3.2Ω and 8Ω loads, Z_{in} = 476Ω
- Vigortronix VTX-101-003 in MC (moving coil) pre-amplifier, Z_{in} = 261Ω with 47kΩ load
- Xicon 42TU200-RC output transformer gave expected 200Ω load with 8Ω winding. I found the secondary was actually a centre-tapped (CT) winding, which gave 2Ω as the correct load for the 3.2Ω winding. The Peak uncovered a winding error here! This was no loss, as I soon developed a distributed load germanium output stage to use the CT output winding. Fig.13 shows the Xicon transformer connected to an 8Ω speaker, giving the expected 200Ω reflected load.

Fig.10. 0.22Ω wire-wound resistor with unusually high parasitic inductance. These resistors caused problems when used as source/emitter resistors in audio power amplifiers

Fig.11. 'Normal' wire-wound resistor inductance

Fig.12. A fusible metal-film resistor exhibits negligible inductance

Currawong inspiration

I wish I had got round to trying cheap 100V line transformers for output transformers in a valve amp like the recent *Currawong Valve Amplifier* design (*EPE*, November 2015). Sifting through the vast number of variations produced to find the right one was a massive task I never finished. This is because the load impedances aren't specified, manufacturers usually just quote the power drawn from the line – typically 1.25W, 5W… Although it is perfectly possible to calculate the impedance knowing just the power tap and the load impedance, it is much more accurate to measure it directly. Here are the theoretical impedance values from *R* = V^2/P where *P* is the power tapping and *V* =100V RMS:

15W	660Ω
12W	827Ω
6W	1650Ω
5W	2000Ω
4W	2500Ω
3W	3330Ω
2.5W	4000Ω
2W	5000Ω
1.5W	6500Ω
1.25W	8kΩ
1W	10kΩ
0.5W	20kΩ

100V line transformers can only be used with push-pull valve amplifiers since they cannot tolerate a DC component in the core because they are un-gapped. This means they must have a centre tap on the winding. Most of my 100V line transformers had to be instantly dismissed for valve use because the tappings were on the secondary low-impedance side. To measure the impedance on the primary it is essential to load the secondary with the specified impedance, usually an 8Ω or 16Ω resistor (see Fig.14). I had one Eagle P038 transformer which measured half the calculated impedance and whose centre tap was not quite mid-way. I finally found a 20W

Fig.13. Measuring the impedance of an 8Ω speaker reflected through the Xicon output transformer. Your delicate germanium transistors will be safe

Fig.14. When measuring the impedance of transformers it is essential they are loaded with the correct load resistance

Adastra transformer that gave an 8kΩ load with a centre tap, see Fig.15. Note this measures 2kΩ each way from the centre tap because impedance ratio is turns ratio squared. This is ideal for a pair of EL84 pentode valves, beloved by guitarists for the basis of a 10W guitar amp, as shown in Fig.16. It also had a 16Ω tap on the secondary for use with light paper-cone 16Ω 12-inch Celestion G12 speakers, often cited as being an essential component of the 'British guitar sound'.

Other measurements

I measured the output impedance of my test bench amplifier (*EPE*, Dec 2014) in constant-current mode and found it was 24Ω. I calculated it to be 50Ω. (Important note – be careful when doing measurements like this, it could damage the Peak meter.) The Peak is also useful for measuring input impedance and input capacitance, often due to the Miller effect and RF filters. You need to be careful the 1.5V peak-to-peak pulsed 1kHz test signal does not cause overloading, as this will alter the reading.

Fig.15. This Adastra 20W 100V line transformer is ideal for small valve amplifiers. It gives an 8kΩ anode-to-anode load with a centre tap. Stock code 952.440UK. Order code from CPC is DP33221, £7.50 plus VAT

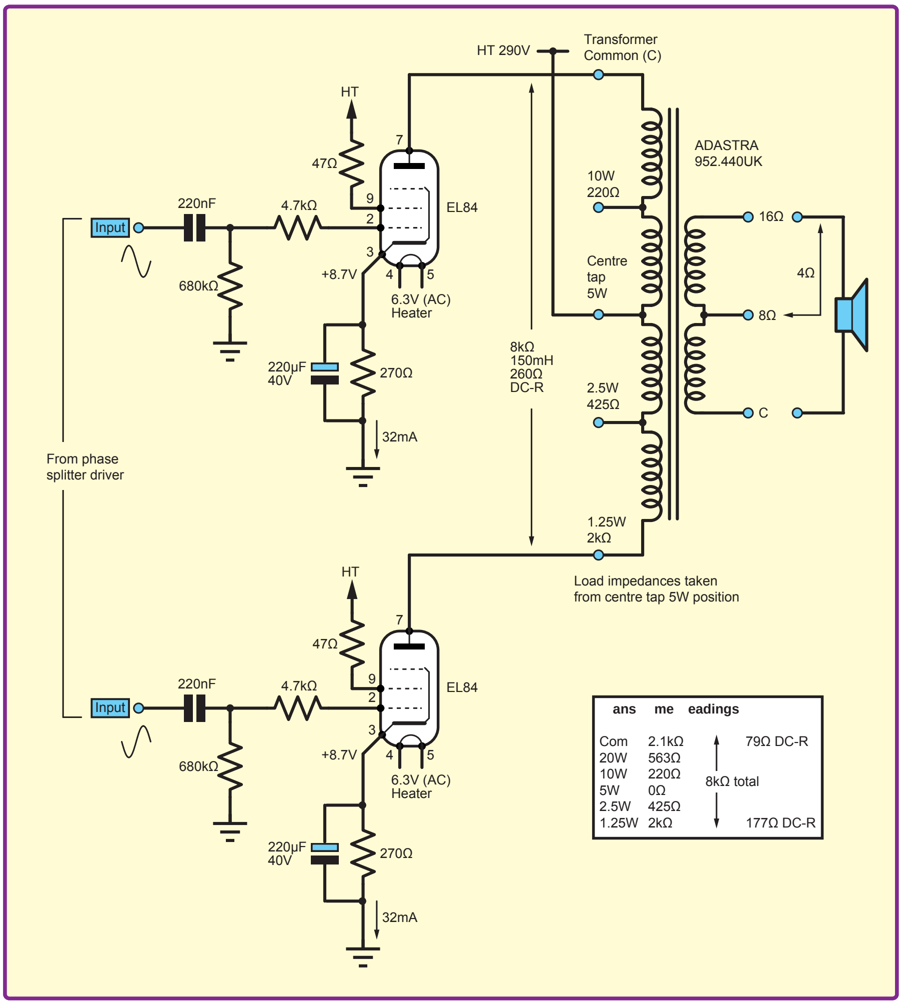

Fig.16. A typical valve output stage suitable for a small guitar amp using the Adastra transformer. Using 100V line transformers will save about £40.00, but you need a Peak analyser to check the impedances are right

Surface-mount tweezers

One part of my work is reverse engineering to work out the circuits of competitors' products. Schematics have always been hard to get, but at least in the old days components had their values marked. Not anymore! – most surface-mount ceramic capacitors have no markings, possibly just a vague tint indicating the dielectric used. Pick-and-place machines have no need to read, they just put on what's in the tube. Using the LCR45 with the optional plug-in SMD03 tweezers illustrated in Fig.1, Fig.17 and Fig.18 produced a solid measuring system. No more messing about with meter probes pinging that unknown cap into the component-eating carpet black hole!

Cost effective

The cheapest alternative to the Peak LCR45 is a Tenma 72-6948 impedance meter (which only works at 1kHz) and a separate LCR meter, both only offer 3.5 digits, as opposed to the Peak's 4 digits. Together, these would cost over twice the price of a Peak. The only advantage of the Tenma is its large display, which is useful for teaching.

An OLED option for the Peak analysers would greatly improve visibility, but then battery life would be very short. I notice the unit uses the unusual mini 12V GP23A battery – just like the older Peak LCR40. I have to keep these batteries especially in stock for my Peak analysers. The GP23A will last a long time, thanks to the Peak's current consumption of 4mA. Also, the LCR45's reading speed is now almost 10-times quicker than the old LCR40.

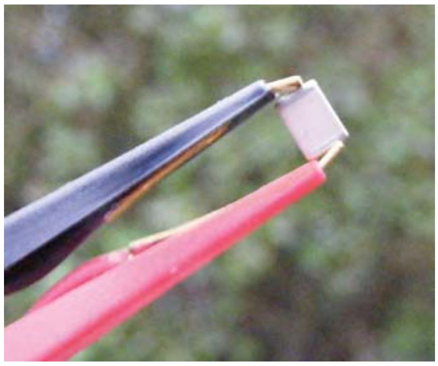

Fig.17. Surface-mount tweezers are available. Here they hold a typical unmarked ceramic capacitor. It is actually a 3.3nF COG type, but you would never know until you measured it

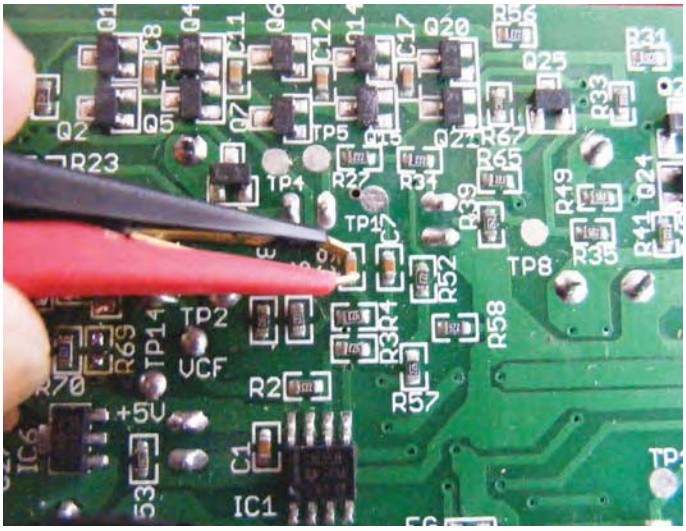

Fig.18. Measuring a capacitor in-circuit on a PCB. Although not an accurate technique, the Peak deals with parallel components better than most LC meters

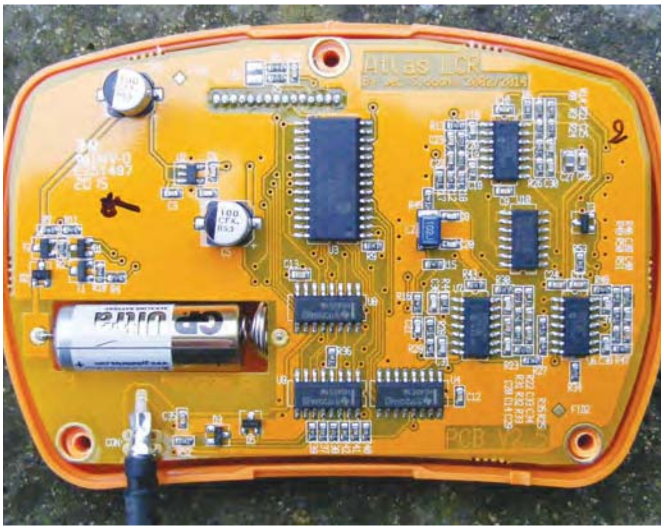

Fig.19. Good-quality internal construction of the unit. (PCBs don't have to have green solder resist!)

Happy termination

Overall I would say this is an essential piece of equipment for any audio or RF circuit designer who can't afford a £5k Agilent rig. Now, if only Peak could do something to measure total harmonic distortion. I'm tired of hiring expensive bench analysers to test power amplifier designs. Imagine it, a little pocket box that would give you THD at say 100Hz, 1kHz and 10 kHz down to 0.001%.

Purchase and further information

The LCR45 is available from Peak for £93 (incl UK p&p and VAT). Further details at: **www.peakelec.co.uk/acatalog/lcr45.html**

DCA75 update

Since reviewing Peak's DCA75 in *EPE*, Sept 2015, I've tested hundreds more devices on it. The new software update installed without problems from the website, even for me – 'Mr. Analogue'! The Peak designer has added a few things I had asked for, such as V_{sat} for bipolar transistors, R_{on} for JFETs and the problem with LM317 voltage regulators was also fixed.

One thing I've noticed is that some transistors that fail to operate in a circuit, still measure fine on the DCA75. I've found this is usually because the device is breaking down at a higher voltage than the analyser tests at. I had some BF245A JFETs used in a ±12V circuit that broke down causing an offset. This problem is rare however, since 95% of transistor failures are definite hard faults.