Passive Component Testing

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Getting the most out of your passive component analyser

A COMPONENT analyser is an instrument that greatly simplifies the testing of passive or active components. Not only is such an instrument capable of carrying out a variety of tests it can also identify a component automatically.

Traditional LCR (inductance-capacitance-resistance) bridges are inherently complex and very time consuming to use. Apart from connecting the component on test to the instrument, a modern passive component analyser (such as Peak Electronic Design's Atlas LCR Analyser) does everything automatically. Not only will the device tell you what type of component is being tested but it will also display relevant additional data, such as the measured self-inductance of a low-value wirewound resistor.

The Atlas LCR Passive Component Analyser offers the following features:

- ☆ Automatic Component Identification
- ☆ Automatic Test Frequency Selection (DC, 1kHz, 15kHz and 200kHz)
- ☆ Delayed or Instant Analysis (for "hands-free operation")
- ☆ Auto Power-Off
- ☆ Probe and Test Lead Compensation
- ☆ Interchangeable Probe Sets
- ☆ Automatic Ranging and Scaling
- ☆ 1% Basic Accuracy

The passive component analyser automatically selects the best signal level and frequency for the particular component under test. The instrument uses "intelligent software" and, in order to ensure precision, all internal calculations are performed with floating point mathematics and values are displayed in properly formatted and easy-to-read engineering units, e.g. 15 9pF, 11 05Ω, etc.

The specifications of the Atlas LCR passive component analyser are as shown in Table 1.

Passive component analysers are primarily designed for carrying out measurements of components "out of circuit". They *should not* be used to carry out "in circuit" measurements as the readings obtained are likely to be significantly affected by the presence of other components. If, in spite of this, you are tempted to make measurements of components in-circuit it is absolutely ***essential*** to ensure that the power is removed from the circuit (or batteries disconnected) and any residual charge is removed from any capacitors that might be present.

A passive component analyser (of any type) should ***never*** be connected to powered equipment/components or to equipment/components with any stored energy (e.g. charged capacitors). Failure to comply with this warning may result in personal injury and damage to the equipment under test, as well as damage to the component analyser itself.

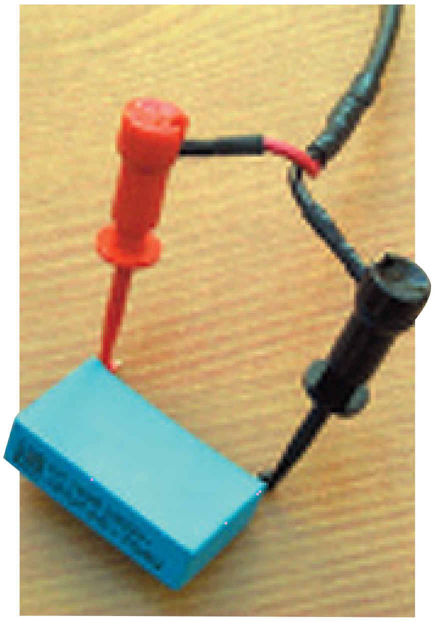
The Atlas LCR Analyser is designed to operate with components connected on an individual basis. Testing of other components that are outside the supported range or that are part of component networks may give erroneous and misleading results.

By default, the analyser uses "delayed analysis". If you press the "On-Test" button to begin an analysis the instrument will power-up and then delay its measurement for five seconds in order to provide you with an opportunity to connect to the component on test. This is a useful facility but it can be somewhat time wasting if you have already made the necessary connections before switching the unit on!

If this is the case you should press the On-Test button a second time when the instrument indicates that the delay period has started. This will bypass the delay and start the measurement process. Once a set of measurements is complete (and before the results are displayed) the component on test can be disconnected from the analyser.

Results are displayed on screen one at a time and pressing the "Scroll-Off" button allows you to move from one screen to the next. If you reach the last screen of results, pressing Scroll-Off will return you to the first results screen again. The component analysis can be started again at any time by pressing the On-Test button.

After carrying out a probe compensation routine, the first stage in making a measurement with the LCR Analyser involves connecting it to the component on test



A variety of different probes are provided for use with the Analyser. These include long-reach grabbers (shown here), SMD clips and crocodile clips

Table 1: Specifications of the Atlas LCR Passive Component Analyser

Inductance:	Range	1µH to 10H
	Resolution	0·4µH min., 0·8µH typ.
	Accuracy	±1% ±0·8µH
Capacitance:	Range	0·4pF to 10,000µF
	Resolution	0·1pF min., 0·3pF typ.
	Accuracy	±1% ±0.3pF
Resistance:	Range	1Ω to 2MΩ
	Resolution	0·3Ω min., 0·6Ω typ.
	Accuracy	±1% ±0·6pF
Peak Test Voltage:	±1·05V	
Peak Test Current:	±3·25mA	
Test Frequency:	1kHz ±11%, 15kHz ±11%, 200kHz ±200ppm	
Sine Purity:	–60dB second harmonic	

If you change the probes on any analyser, it is good practice to run through the short compensation procedure. This ensures that the probes' own inductance, capacitance and resistance are automatically taken into account when making subsequent measurements. The recommended procedure is described later.

Testing Resistors

The analyser can be used to test most common types of resistor. Depending on the value of the component on test, it will automatically select the most suitable test frequency. Low frequencies (e.g. 1kHz) are used to test large value inductors whilst high frequencies (e.g. 200kHz) are used to test small value inductors.

Large Value Resistors

For resistance values of greater than about 10Ω the following values are displayed on the instrument:

- Resistance value (10Ω to 2MΩ with a minimum resolution of 0 5Ω)
- Typical readings for various types of resistor are listed in Table 2.

Low value resistors

For resistance values of less than 10Ω the following values are displayed when the instrument's scroll button is pressed:

- Resistance value (0 5Ω to 10Ω with a minimum resolution of 0 5Ω)
- Inductance value (with a minimum resolution of 0 1µH)
- Test frequency (1kHz, 15kHz or 200kHz)

Typical readings for various types of low value resistor are listed in the Table 3. Probe compensation is very important when analysing low value resistors, as discussed later.

Low value inductors (less than 10µH) and low value resistors (less than 10Ω) are treated as a special case by the Atlas LCR analyser. This is because low value inductors and low value resistors can exhibit very similar characteristics at the test frequencies generated by the instrument.

Pressing the Scroll button will display the values of resistance and inductance that the analyser has measured. Note that the test frequency displayed is the frequency used for the measurement of the resistor's self-inductance (not for the measurement of resistance).

Table 2: Typical readings for large value resistors

Component On Test	***Measured Resistance***
15Ω 15W metal clad resistor	14·9Ω
33Ω 2W carbon film	33·1Ω
100Ω 2·2W vitreous enamelled	101·1Ω
620Ω 0·25W metal oxide film	616·6Ω
4·7kΩ 0·25W metal oxide film	4·702kΩ
1·8MΩ 0·25W carbon film	1·761MΩ

Showing a measured resistance of 14·9Ω

Table 3: Typical readings for low value resistors

Component On Test	***Measured Resistance***	***Inductance***	***Test Frequency***
0.1Ω 2.2W vitreous enamelled wirewound	0·1Ω	0·4µH	200kHz
1Ω 7W ceramic coated wirewound	1·0Ω	0·4µH	200kHz

Testing Inductors

The analyser can be used to test most common types of inductors, coils and chokes. It is also possible to carry out some basic tests on transformers (including detecting short circuit turns).

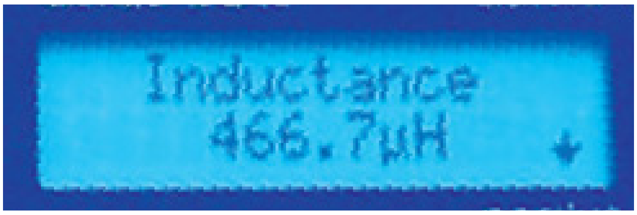
Depending on the value of the component on test, the analyser will automatically select the most suitable test frequency. Low frequencies (e.g. 1kHz) are used to test large value inductors whilst high frequencies (e.g. 200kHz) are used to test small value inductors.

The following values are displayed on the instrument when the scroll button is pressed:

- Inductance value (1µH to 10H with a minimum resolution of 0 5µH)
- D.C. resistance (0 5Ω to 1kΩ with a minimum resolution of 0 5Ω)
- Test frequency (1kHz, 15kHz or 200kHz)

Typical values for various types of inductor are listed in Table 4.

Probe compensation is very important when analysing low value inductors, as discussed later.



The measured value (466·7µH) of a 470µH inductor is displayed on the instrument's LCD screen. In order to obtain the d.c. resistance of the inductor (and to determine it's Q-Factor) it is necessary to press the Scroll-Off button

Table: 4 Typical values for various types of inductor

Component On Test	Measured Inductance	D.C. Resistance	Test Frequency
100µH ferrite-cored inductor	86·4µH	0·0Ω	200kHz
470µH ferrite-cored inductor	469·2µH	0·3Ω	200kHz
10mH miniature ferrite pot-cored inductor	10·0mH	4·2Ω	1kHz
10mH standard ferrite pot-cored inductor	10·33mH	18·9Ω	1kHz
2H iron-cored inductor	2·05H	206Ω	1kHz

Capacitance Measurement

The component analyser uses two different methods to analyse capacitors, a.c. impedance analysis for low value capacitors (less than about 1µF) and d.c. transient analysis for larger capacitors (about 1µF to 10,000µF). The unit will automatically identify the type of capacitor being tested and apply the most appropriate test method.

Low Value Capacitors

Low value capacitors include ceramic, polyester, polystyrene, mylar and mica dielectric capacitors with values generally less than 1µF, or so. Such capacitors tend to be unpolarised (though some tantalum electrolytic capacitors are available with values as low as 100nF or 0 1µF). The minimum capacitance resolution of the instrument is about 0 1pF.

The component analyser uses a high purity sinewave signal of 1kHz, 15kHz or 200kHz to analyse low value capacitors. Following analysis of the capacitor, the capacitance value is displayed first. Thereafter, pressing the Scroll-Off button will display the frequency at which the capacitance was measured.

Depending on the value of the component on test, the analyser will automatically select the most suitable test frequency. Low frequencies (e.g. 1kHz) are used to test large value capacitors whilst high frequencies (e.g. 200kHz) are used to test small value capacitors.

For capacitance values of less than about 1µF the following values are displayed on the instrument when the scroll button is pressed:

- Capacitance value (0 1pF to 1µF with a minimum resolution of 0 1pF)
- Test frequency (1kHz, 15kHz or 200kHz)

Table 5: Example low value capacitor readings

Component On Test	Measured Capacitance	Test Frequency
47pF 100V ceramic	44·1pF	200kHz
200pF 100V ceramic	186·4pF	200kHz
470pF 250V polystyrene	487·2pF	200kHz
1nF 250V ceramic	791·2pF	200kHz
10nF 50V ceramic	7·345nF	15kHz
27nF 1kV polyester	26·1nF	1kHz

Here the value of a capacitor is displayed on the instrument's LCD screen. The arrow displayed in the bottom right corner indicates the availability of more information which will be displayed when the Scroll-Off button is pressed

Typical values for various types of low value capacitor are listed in Table 5. Probe compensation is very important when analysing low value capacitors, as discussed later.

Large Value Capacitors

Capacitors larger than about 1µF are treated differently, instead of being tested with an a.c. signal, they are tested with d.c. The following information is displayed when the Scroll button is pressed:

Table 6: Example high value capacitor readings

Component On Test	Measured Capacitance	Test Frequency
1µF 63V polycarbonate	1·023µF	d.c.
4·7µF 63V axial electrolytic	4·718µF	d.c.
22µF 10V tantalum electrolytic	21·62µF	d.c.
47µF 16V radial electrolytic	47·96µF	d.c.
1,000µF 16V radial electrolytic	1·056mF	d.c.

● Capacitance value (1μF to 10mF with a minimum resolution of 1nF)

● Test frequency (d.c.)

Typical values for various types of capacitor are listed in Table 6.

Measuring Characteristic Impedance

Provided you have a reasonable length of transmission line or coaxial cable (say 5m to 10m, or more) available, one interesting use of a passive component analyser is that of providing an estimate of the characteristic impedance of the cable or line. Two separate measurements are required:

1. The inductance of the cable or line is measured with the far end short-circuit, and

2. The capacitance of the cable or line is measured with the far end open-circuit.

The characteristic impedance can be determined from the following formula:

$$Z_0 = \sqrt{\frac{L}{C}}$$

where Z_0 is the characteristic impedance (in Ω), L is the measured value of inductance (in H), and C is the measured value of capacitance (in F).

To simplify the arithmetic a little, the formula can be expressed in terms of μH and pF, as follows:

$$Z_0 = 31{\cdot}6 \times \sqrt{\frac{L}{C}}$$

where Z_0 is the characteristic impedance (in Ω), L is the measured value of inductance (in μH), and C is the measured value of capacitance (in nF).

The following example is based on measurements made on a drum (of unknown length) of RG213 coaxial low-loss feeder cable:

Inductance (measured with far end of cable short circuit): 22 5μH

Capacitance (measured with far end of cable open circuit): 7 5nF

Using the formula stated previously:

$$Z_0 = 31{\cdot}6 \times \sqrt{\frac{L}{C}} = 31{\cdot}6 \times \sqrt{\frac{22{\cdot}5}{7{\cdot}5}}$$

$$= 31{\cdot}6 \times \sqrt{3} = 31{\cdot}6 \times 1{\cdot}732 = 54{\cdot}7\Omega$$

This next example is based on measurements made on a 10m length of standard TV coaxial downlead cable:

Inductance (measured with far end of cable short circuit): 2 9μH

Capacitance (measured with far end of cable open circuit): 560pF (= 0·56nF). Using the formula stated previously:

$$Z_0 = 31{\cdot}6 \times \sqrt{\frac{L}{C}} = 31{\cdot}6 \times \sqrt{\frac{2{\cdot}9}{0{\cdot}56}}$$

$$= 31{\cdot}6 \times \sqrt{5{\cdot}2} = 31{\cdot}6 \times 2{\cdot}3 = 73\Omega$$

In this screen shot the d.c. resistance (0·3Ω) of an inductor is displayed

Measuring Q-Factor

Although the passive component analyser does not indicate Q-factor directly, a rough estimate of the Q-factor of an inductor can easily be obtained. The value obtained will be sufficient to provide an indication of the "goodness" of the component as well as its suitability for use in a filter or resonant circuit application. The determination of Q-factor requires knowledge of:

1. The inductance of the inductor

2. The d.c. resistance (loss resistance) of the inductor

The approximate Q-factor (see later) of the inductor can be determined from the following formula:

$$Q = \frac{2\pi f L}{R}$$

where Q is the approximate Q-factor of the inductor, f is the frequency of the current applied to the inductor (i.e. its operating frequency), L is the measured value of inductance (in H), and R is the measured value of resistance (in Ω).

To simplify the arithmetic a little, the formula can be expressed in terms of mH and kHz (or μH and MHz) as follows:

$$Q = 6{\cdot}28 \times \frac{fL}{R}$$

where f is the frequency in kHz or MHz, L is the measured value of inductance (in either mH or μH), and R is the measured value of resistance (in Ω).

The following example is based on measurements made on a 10mH inductor used in a switched-mode power supply operating at 15kHz:

Inductance: 10 37mH

d.c. resistance: 18 9Ω

Using the formula stated previously, and working in units of mH and kHz gives:

$$Q = 6{\cdot}28 \times \frac{fL}{R} = 6{\cdot}28 \times \frac{15 \times 10{\cdot}37}{18{\cdot}9}$$

$$= 6{\cdot}28 \times \frac{155{\cdot}55}{18{\cdot}9} = 51{\cdot}7$$

Pressing the Scroll-Off button displays the test frequency (200kHz) on the instrument's screen

The next example is based on measurements made on a long-wave (200kHz) aerial coil:

Inductance: 1 087mH

D.C. resistance: 27 2Ω

Using the formula stated previously, and once again working in units of mH and kHz gives:

$$Q = 6{\cdot}28 \times \frac{fL}{R} = 6{\cdot}28 \times \frac{200 \times 1{\cdot}087}{27{\cdot}2}$$

$$= 6{\cdot}28 \times \frac{217{\cdot}4}{27{\cdot}2} = 50{\cdot}2$$

The following example is based on measurements made on the search coil of a metal detector working in a phase-locked loop at a frequency of 1MHz:

Inductance: 80 8μH

D.C. resistance: 2 2Ω

Using the formula stated previously, and this time working in units of μH and MHz gives:

$$Q = 6{\cdot}28 \times \frac{fL}{R} = 6{\cdot}28 \times \frac{1 \times 80{\cdot}8}{2{\cdot}2}$$

$$= 6{\cdot}28 \times 36{\cdot}73 = 231$$

It is important to note that the assessment of Q-factor based on passive component analyser readings makes use of the d.c. loss resistance of the component, and not the true loss resistance of the component at whatever operating frequency is present with the component connected "in circuit". This true loss resistance is made up from the sum of the d.c. and a.c. loss resistances and thus the true working Q-factor for an inductor will always be less than the Q-factor based on a measurement of its d.c. loss resistance.

Checking the inductance of a metal detector pulse induction search coil

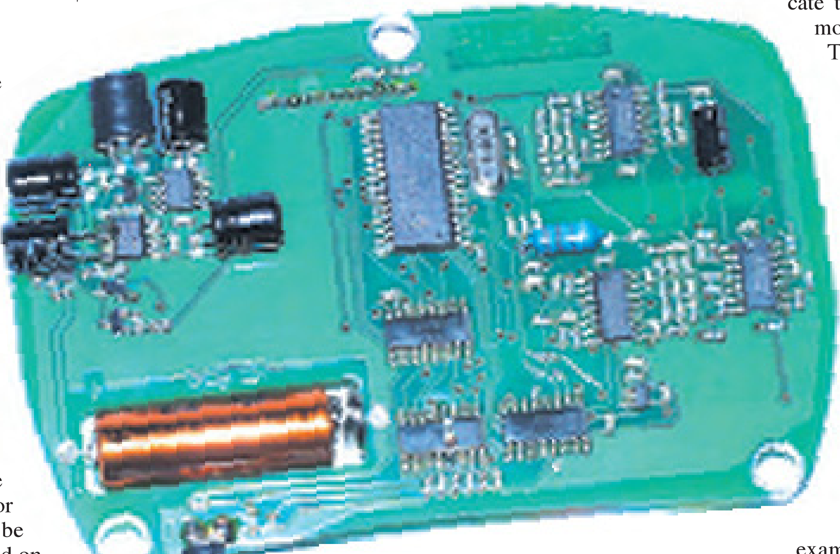
In most cases, however, the a.c. loss resistance will be significantly lower than the d.c. loss resistance and thus can usually be neglected when only an approximation of Q-factor is required. Despite this, it is worth remembering that the Q-factor obtained by the method described earlier represents a "best case" or "most optimistic" scenario!

Testing Transformers

A passive component analyser can be used to carry out some basic tests on transformers as well as detecting short circuit turns. The inductance of each winding can be measured and compared with a "known good" component. Where a significant reduction in inductance is detected this will indicate the presence of one or more short circuited turns.

The data in Table 7 is based on "known good" and "known faulty" components (12VA transformers with 230V primaries and 12V secondaries rated at 1A) and will serve as an illustration.

It is interesting to note how the presence of shorted turns can be much more easily detected by using inductance measurement than by using resistance measurement – as the examples in Table 7 show!



Layout of components, mostly surface mount devices, on the printed circuit board

Table 7: Testing Transformers

Inductance Measured	*Measured Inductance*	*DC Resistance*	*Test Frequency*
Known good component Primary (220V) winding	2·134H	226Ω	1kHz
Short-circuited primary turns Primary (220V) winding	320·3μH	207·2Ω	1kHz
Short-circuited secondary turns Primary (220V) winding	866·3μH	226Ω	1kHz

Probe Compensation

Probe compensation is needed to ensure that the Atlas LCR Analyser takes the probe characteristics into account when analysing components. The probe's inductance, capacitance and resistance are effectively subtracted from all subsequent measurements so that displayed readings relate to the component under test rather than the probes as well.

It is generally not necessary to perform probe compensation unless you are changing the probe types or the readings for an open circuit are more than ±2pF or the readings for a short circuit are more than 1Ω and/or ±2μH. Simply removing the probes and re-attaching them does not require a probe compensation procedure.

If you change the analyser's probes (perhaps to facilitate connection with a

Tips For Better Results

● Ensure that you carry out the recommended probe compensation procedure whenever you change the probes used with the component analyser or before making measurements on low value components (e.g. resistors of less than 10Ω)

● Ensure that the components on test are within the measurement range of the instrument

● Be aware that measurements of low inductance, capacitance and resistance will be performed to a reduced resolution when compared with larger values

● Remember that, once measurements have been made, the results can be scrolled through without the need for the component on test to remain connected to the analyser

● Replace the analyser's battery on a regular basis (at least once every 12 months is recommended by the manufacturer)

● Do not hold the probe tips or component leads when making the measurements

● ***Do not*** attempt to make any measurements on a *live* network or circuit (this may cause irreversible damage to the instrument and the results are highly likely to be erroneous!)

● Remember to fully discharge large value capacitors before connecting them to the analyser

different type of component), it is good practice to run through the short compensation procedure. This ensures that the probes' own inductance, capacitance and resistance are automatically taken into account for subsequent measurements.

A typical probe compensation procedure is as follows:

1. To start the compensation procedure, simply press and hold the On-Test button until the start of the calibration routine is indicated on the display.

2. After a short delay, the unit will then prompt you to short the probes together. Note that if you are using the Atlas LCR's optional SMD tweezers, you should short the tips using the supplied dummy short circuit (Atlas describes this as a "dog tag").

3. After shorting the probes the unit will ask you to open the probes. If this procedure has been successful, the unit will simply display the message "OK" before switching itself off.

At this point the parasitic and stray characteristics associated with the test leads (and indeed the component analyser itself) will be stored in non-volatile memory. All further tests will have these values subtracted from the measured values, therefore displaying the characteristics of the component alone.

The foregoing procedure will cope with most situations. However, the following enhanced procedure is recommended in cases where you might need to ensure a more repeatable compensation result (for example when making repeated high-precision measurements on low-value components):

1. Ensure that the component analyser is switched off.

2. Clip the test leads to a short length of clean tinned copper wire.

3. Ensure that you are not touching the tinned copper wire, test clips or connections and that these are placed on an insulated surface.

4. Press and hold the On-Test button until the display shows "Probe Compensation". Once again, ensure that you are not touching the test clips or connections. The analyser will ask you to "short the probes" but there is no need to do this as the short-circuit is already in place. Simply wait a few seconds until the next instruction appears!

5. Follow the instruction to "open the probes" by unclipping the red clip from the tinned copper wire and then let go of the test leads and connections. The display will then show "OK" within a couple of seconds.

Finally, the probe compensation sequence should be tested using steps 6 to 9:

6. Ensure that nothing is connected to the test clips.

7. Briefly press the On-Test button. The analyser should then measure and display a capacitance value that is very close to 0pF (±1pF).

8. Now connect the two clips to the tinned copper wire and briefly press the On-Test button again. The analyser should display "Low resistance and inductance" and then, after pressing the "Scroll-Off" button should display a resistance of close to 0Ω (i.e. less than 1Ω) and an inductance of close to 0μH (±0 5μH).

9. If the readings in steps 7 and 8 are not obtained it is essential to repeat steps 1 to 5 of the compensation procedure before once again rechecking the effectiveness of the probe compensation.

Obtaining the Atlas LCR

The Atlas LCR passive component analyser is available from Peak Electronic Design Ltd, Dept EPE, Atlas House, Kiln Lane, Harpur Industrial Estate, Buxton, Derbys SK17 9JL. Tel: 01298 70012. Further details of the instrument can also be obtained from **www.peakelec.co.uk**. Its current price is £69, including UK delivery and VAT. □