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tech tips

Interpreting the LC102 AUTO-Z Readings

A few capacitors and inductors may test differently than you might expect because of variations in the components. These components show a wide range of results when tested on bridges and other digital testers, as well. This Tech Tip explains why these components show different results, and how to interpret the LC102 test results on them.

Some Capacitors Measure Differently Than Marked

The capacitor value test simply involves pressing the CAPACITOR VALUE button on the right side of the panel. Entering the marked value and tolerance causes the readout to also show the GOOD/BAD results for value. Here are a few special conditions to know about.

1. Understanding Tolerances: Capacitors often have different positive and negative tolerances. You need to enter both into the LC102. For example, a common specification for electrolytic capacitors is +80%, -20%. This means that the value of a 50 uF capacitor could be 80 percent higher (50 x 1.8 = 90 uF) or 20 percent lower (50 x 0.8 = 40 uf) and still be within the rated tolerance.

Tolerances are sometimes marked on the capacitor. Details on reading standard capacitor codes are included in pages 65 to 68 of the LC102 instruction manual. If the capacitor you want to test does not follow one of these industry standard methods of marking tolerance, check the parts list in the service literature to see if it shows a tolerance.

2. Electrolytics Normally Read High: All Z Meters (as well as most other digital capacitor value testers) use a DC time-constant circuit to determine capacitor value. This test method usually shows an electrolytic capacitor to have a value higher than its marked value because of the way the electrical properties of the water inside the capacitor change with frequency.

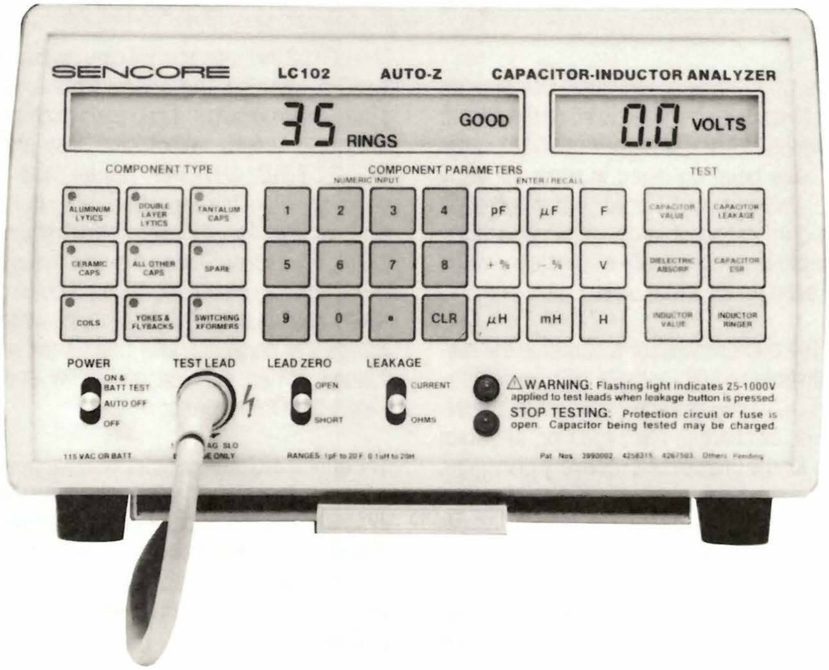

Fig. 1: The LC102 AUTO-Z — microprocessor controlled for error-free testing.

The water in the electrolyte solution carries the electrical charge from the negative metal plate to the surface of the insulating oxide dielectric on the positive plate. Studies by the Physics Department of South Dakota State University (SDSU) show that the electrical resistance of the water increases at higher frequencies because of the resonant properties of the water molecules. This increased resistance, in series with the capacitive reactance of the capacitor, causes a 1 kHz bridge to measure the value lower than its true value. Since most capacitor manufacturers test the electrolytic capacitor with a 1 kHz LCR bridge, electrolytic capacitors are often marked with a lower value than the value they show at DC or low frequencies. The DC AUTO-Z test shows the correct, higher value that the capacitor produces in a DC circuit.

Extensive testing by Sencore engineers and by the SDSU researchers shows that the manufacturer's tolerance includes this frequency effect. Unless the capacitor is defective, the AUTO-Z will read an 80% capacitor within 80% of its marked value. A 20% capacitor, on the other hand, will read closer to the marked value (and within the 20% tolerance) than an 80% component with the same ratings. This is why it is important to apply the correct tolerance to testing before deciding if a value seems too high compared to the marked value.

Relating Dielectric Absorption To The Circuit

Dielectric absorption (D/A) prevents a capacitor from completely discharging. All capacitors have some D/A, but excessive D/A causes problems. Sencore developed, and patented, a relative test for D/A on the earlier Z Meters to identify this important capacitor defect. The previous test was based on the change in the capacitor's value before and after charging it to its full rated voltage. A value change indicated that there was some D/A present, but the results were only relative, and did not correlate directly to the D/A amount.

The amount of value change with this original D/A test depends on several variables, the largest being: 1. How long the capacitor had been charged, 2. How much time elapsed between releasing the LEAKAGE button before pressing the VALUE button a second time, 3. The charging voltage, 4. The capacitor's value, as well as 5. The amount of D/A. Despite these differences in numerical results, the test positively confirmed the presence of D/A, which helped find bad capacitors which would otherwise have gone unnoticed.

Since the LC102 has a dedicated D/A test, its value test circuits do not need to show the effects of D/A like the earlier Z Meters. The LC102 value circuits have been changed in order to allow testing of values over 1 Farad, and to increase the speed in testing of large value capacitors. These improvements virtually eliminate the value change seen on the other units.

The LC102 microprocessor automates the dielectric absorption test for more reliable results. The AUTO-Z charges each capacitor to a reference level, discharges the capacitor, and then monitors for the undesirable recovery of voltage. The microprocessor controls the charging and discharging time for repeatable results. All capacitors are tested with the same voltage, so that the recovered voltage can be converted directly to a percentage. The percentage agrees closely with the standard laboratory test, but, unlike the lab method, does not require several hours of "setting" time.

Most capacitors will show a different amount of dielectric absorption if they have recently had voltage applied, either from the circuit or from the LC102 leakage supply. The time needed to eliminate this effect varies from a few seconds to several hours, depending on the capacitor and the previously applied voltage. Here's why.

Consider a capacitor with 3% of D/A. When tested with a known voltage, such as with the laboratory method or with the new LC102 test, the capacitor will recover 3% of the test voltage a short time after being charged and discharged. The test voltage used by the LC102 is 3 volts, so 3% represents a voltage recovery of only a few millivolts (the percentage is not directly related to voltage, because the discharge and recovery periods have been speeded up compared to older methods). If this same capacitor had recently been charged to 100 volts, the 3% D/A will cause it to recover 3 volts after a period of time. If it had been charged to 1000 volts, the recovered voltage could reach 30 volts.

If the capacitor is being tested with the LC102 while it is still recovering voltage from a previous charge, the voltage adds to the amount developed from the microprocessor-controlled test. This causes the percentage to read higher than the "at rest" level until the original D/A recovery effects have passed.

This, by the way, is the reason that other Z Meters show higher levels of D/A on high voltage electrolytic capacitors than on low voltage ones. The other meters use their value test to indicate D/A. The value test uses the same voltage to test capacitors of any voltage rating, so a given D/A percentage produces a larger value variation if the capacitor was charged to a higher voltage.

The LC102 includes special circuits that hold up the D/A test until the effects from a previous charge have reduced to a level which provides resonable results. When you first press the DIELECTRIC ABSORP button, the LC102 senses whether the capacitor is already recovering a voltage. If so, it places a WAIT statement in the digital display. During the time the display is telling you to wait, the microprocessor alternately applies a low impedance discharge path across the capacitor and retests for recovery voltage. When the voltage is low enough, it allows the D/A test to continue.

The effects of a previous charge disappear rather slowly. Remember that the effective resistance in series with the capacitance representing the dielectric absorption effect is several megohms, so even a dead short across the capacitor leads may require several minutes to discharge the D/A voltage.

The time needed to remove the internal charge depends on the capacitor's value, what voltage was previously applied, and its dielectric absorption level. When the WAIT message appears, you may continue the D/A test, release the button (which places the normal LC102 discharge path across the capacitor), or disconnect the capacitor and set it aside to stabilize while you use your AUTO-Z for other tests. If you choose the third option, it is helpful to place a clip lead across the capacitor leads to speed the dissipation of the previous charge.

In most cases, it is faster to perform the D/A test BEFORE the leakage test. Capacitors with excessive dielectric absorption will be found immediately, without needing to wait for the effects of the charge from the leakage test to drop to a low enough level to perform the D/A test.

You may prefer to test for leakage before testing for D/A to see how long the capacitor takes to recover from the application of the leakage power supply voltage. If so, you may wish to compare the unknown capacitor to one you know works correctly to determine the recovery period. A capacitor which takes excessive time to drop to normal D/A readings should be considered questionable.

NOTE: The dielectric absorption test should only be used to test capacitors larger than 0.01 uF. Testing smaller values produces an Error 3 message because the results for smaller capacitors may be misleading.

How much is too much? The LC102 GOOD/BAD limits for D/A cover the most common capacitor applications. The division line between GOOD and BAD depends on which COMPONENT TYPE button has been selected. The limits are:

Type	Percentage
Aluminum Lytic	15
Double Layer	15
Tantalum Caps	15
Ceramic Caps	10
All Other Caps	0

Fig.2: The GOOD/BAD limits for dielectric absorption programmed into the LC102 AUTO-Z

A good technician uses these GOOD/BAD results as a guide, rather than a hard and fast rule. You may wish to reject capacitors with lower levels of D/A if they are used in critical circuits and the circuits are not working correctly. Here's some additional information about the affects of D/A in different circuits.

Capacitors which store a DC voltage to control other circuits must have extremely low levels of D/A. In TV receivers, for example, the capacitor used in the AGC, ACC, AFC, or AFPC detectors will cause incorrect operation if dielectric absorption adds to the circuit's correction voltage. Similarly, capacitors used in sample-and-hold circuits in instruments, or capacitors used in digital-to-analog or analog-to-digital converter circuits need low D/A levels. Dielectric absorption values of 1% or more will often effect these critical circuits.

Capacitors used to couple AC (and block DC) may cause waveform distortion if dielectric absorption is too high. Audio amplifiers often develop distortion with a poor coupling capacitor. However, the D/A will generally have to be between 5% and 15% before it causes problems in these applications. These values may show GOOD on the AUTO-Z, so be certain you judge

Use	Practical Limits
Timing	1%
Sample Hold	1%
Audio Coupling	5% - 15%
Power Supply	15%

Fig. 3: The actual D/A limits depend on the circuit using the capacitor.

the performance of the capacitor on the circuit's operation. If you see waveform clipping, or other distortion, changing the capacitor may solve the problem.

Power supply capacitors can usually tolerate much higher levels of D/A before causing circuit problems. Generally, you will not see a noticeable change in performance until D/A reaches 15%. However, remember that increased dielectric absorption shows the capacitor is beginning to fail, so a capacitor with high levels should not be used as a replacement.

Understanding The Capacitor Leakage Test

The AUTO-Z uses industry standards for the GOOD/BAD limits for leakage testing. Selecting the correct capacitor type with the COMPONENT TYPE buttons, provides the information the microprocessor needs to calculate all direct bad/good results.

Electrolytic Leakage: All electrolytic capacitors have some leakage at their rated voltage, so the capacitor manufacturers adopted industry standards for acceptable limits. Don't worry if a capacitor takes a few seconds before dropping to the GOOD limit. This is especially the case when testing a capacitor with a large value or with a high voltage rating.

Large value capacitors need extra time to charge because they become part of an R-C circuit, along with the output impedance of the leakage power supply. Capacitors with values over 20 microfarads take a few seconds to charge, as explained on page 22 of the LC102 manual.

An electrolytic capacitor, which has not been charged in several weeks, may deform. This results in higher leakage current, while the applied voltage reforms the insulating oxide layer. The AUTO-Z lets you safely reform the capacitor by simply leaving the leakage supply connected until the leakage drops to acceptable current levels. You know the reforming is complete by simply waiting until the GOOD/BAD results show GOOD.

When To Test For Equivalent Series Resistance

The equivalent series resistance (ESR) test only applies to aluminum, tantalum, and double layer electrolytic capacitors. ESR represents all the resistance in series with the plates of the capacitor, which includes the resistance of the connections between the leads and plates, the leads themselves, and the oxide layer. ESR does not include resistance between the plates, since this path represents leakage.

A capacitor with excessive ESR causes trouble when it processes high frequencies, high currents, or both. The ESR becomes less important in smaller value capacitors, because their capacitive reactance (Xc) is much larger than the series resistance (Rs). The Xc drops as operating frequency increases, making Rs more important. When Xc and Rs are equal, the circuit sees the capacitor as half its normal value. When Xc is less than the Rs, the capacitor has even less effect on the circuit.

Filtering capacitors handling large currents can also be affected by ESR, since the voltage dropped across the resistance generates heat. This heat, in turn, causes the capacitor to dry out, causing early failures.

A few examples of high frequency circuits in consumer servicing affected by ESR include TV AGC circuits (15 kHz), FM stereo (19 kHz), and TV stereo circuits (31 kHz). Examples of circuits in industrial and computer servicing include power supplies for TTL digital circuits. All industries use switching power supplies operating at high frequencies, which involve both high frequencies and high power.

Excessive ESR shows a poor lead connection or that the electrolyte is drying out. Discard the bad capacitor and replace it with one with normal series resistance.

	Xc	
f	1 uF	100 uF
10 Hz	15.9K	159
1 kHz	159	1.59
1 MHz	0.159	0.0015

Fig. 4: The ESR becomes significant when it equals or exceeds the capacitive reactance at the circuit's frequency.

Some Inductors Measure Different Values Than Marked

For most inductors, you simply press the INDUCTOR VALUE button and read the digital display to determine the true inductance value. Most inductors read the same value on the AUTO-Z as on different types of value testers. A few, however, show different values, depending on the test method. This does not cause problems if you know the reason for different value readings.

There are three common methods to determine inductance: the LCR bridge, the Q meter, and the AUTO-Z. To understand why each test method gives different values, we need to know a little about how each determines inductance.

The AUTO-Z uses the basic definition of inductance, which defines inductance in reference to the voltage induced when applying a constantly changing current. This determines the inductance without regard to frequency, because the test circuits are resistive, not reactive. The result is the integral (average) value over the operating frequency range of the coil.

The other two methods test an inductor at a single frequency. An LCR bridge determines inductance by measuring inductive reactance at a single frequency, usually 120 Hz or 1 kHz. A Q meter places the inductor in parallel with an adjustable capacitor. A high frequency signal (70 kHz to several MHz) is applied to the parallel combination, and the capacitor is adjusted until reaching resonance at that frequency.

High quality coils measure nearly the same value, whether tested on an LCR bridge, a Q meter, or on the AUTO-Z. These coils have core materials which do not change in permeability with different frequencies. Cores made of powdered iron (ferrite) ceramic, paper, or air show very little variation with applied frequency. Markings on the coil represent the inductance value.

Inductors with laminated iron cores, or with special high permeability materials which produce very high inductance values in a very small volumes, are often very frequency selective. If so, each method used to measure inductance produces a different value. The graph in Fig. 5 shows how one coil changes very severely with different test frequencies, while another changes by a very small amount. The graph stops at 100 kHz because the coil with the largest variation becomes self-resonant (and unusable) at higher frequencies.

The coil with the wide variation is marked 100 mH. Its marked value comes closer to the value measured by the Q meter than to the value shown by either a bridge or the AUTO-Z. Notice, however, that this coil will become unstable if

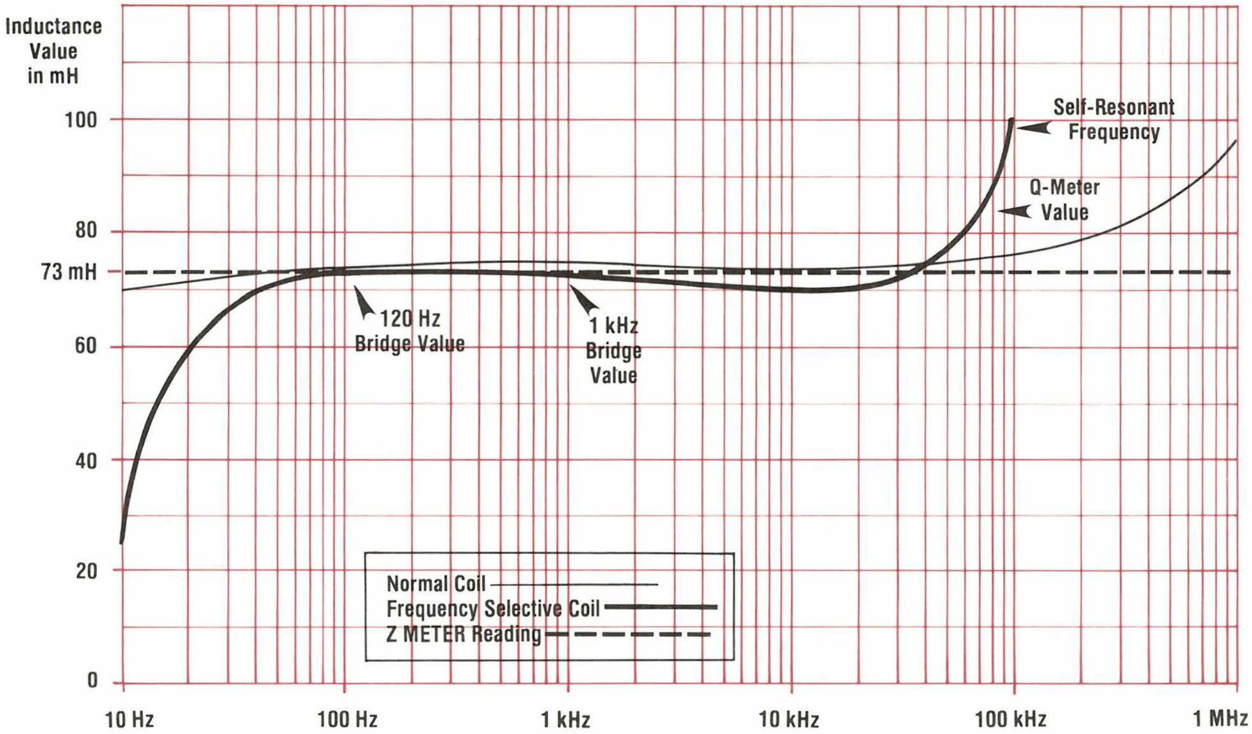

Fig. 5: A frequency selective coil measures differently on each type of value tester. The Z METER shows the average value.

used in a circuit which operates at a slightly higher frequency than used by the Q meter.

The AUTO-Z shows this coil as 73 mH, which represents the flat part of the graph, or the coil's average value. A 120 Hz or 1 kHz bridge measures this coil at the same value as the AUTO-Z, because the coil has flat respose between these two test frequencies. Other coils, however, will show a difference when tested at 120 Hz compared to 1 kHz, meaning that two bridges will give different readings as well.

How do you test such a device when it reads differently with every test method? There are two options. First, most coils test reliably with the AUTO-Z INDUCTOR RINGER test. Second, if the value is important to you, test a known-bad and a known-good coil for comparison. Then, set your own standard cutoff value between the two measured values to base the test on circuit performance.

How The Inductor Ringer Eliminates Value Questions

The question of "which value is right?" has complicated inductor testing for decades. Bridges and Q meters have always shown radically different readings on some coils. To make matters worse, the most common coil problem (shorted turns) changes the inductance (or resistance) value by such a small amount as to be undetectable. Also, many inductors have no "ideal value" marked, so any value test is useless. That's why the AUTO-Z has the patented INDUCTOR RINGER test. The Ringer provides a direct GOOD/BAD result without needing to know anything about the coil, except that its core is not made of laminated metal plates.

All Ringer tests are based on the number 10. A number larger than 10 shows the inductor is good, and a number less than 10 shows that the inductor is bad. For the first time, the AUTO-Z makes this test fully automatically. Simply choose the correct COMPONENT TYPE, press the INDUCTOR RINGER button, and read the digital display. Both the actual number of ringing cycles and a GOOD/BAD result will show in the window.

For these numbers to be reliable, however, you must tell the AUTO-Z which type of coil you are testing with the COMPONENT TYPE buttons. Defects as mild as a single shorted turn are discovered with this sensitive test.

The number 10 remains valid for all inductors down to 10 microhenries. If the inductor has a lower value, you can use a comparison test by first ringing a known-bad inductor and noting the number of ringing cycles. Then, test the suspected bad one and confirm it reads the same number of cycles.

For more information
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