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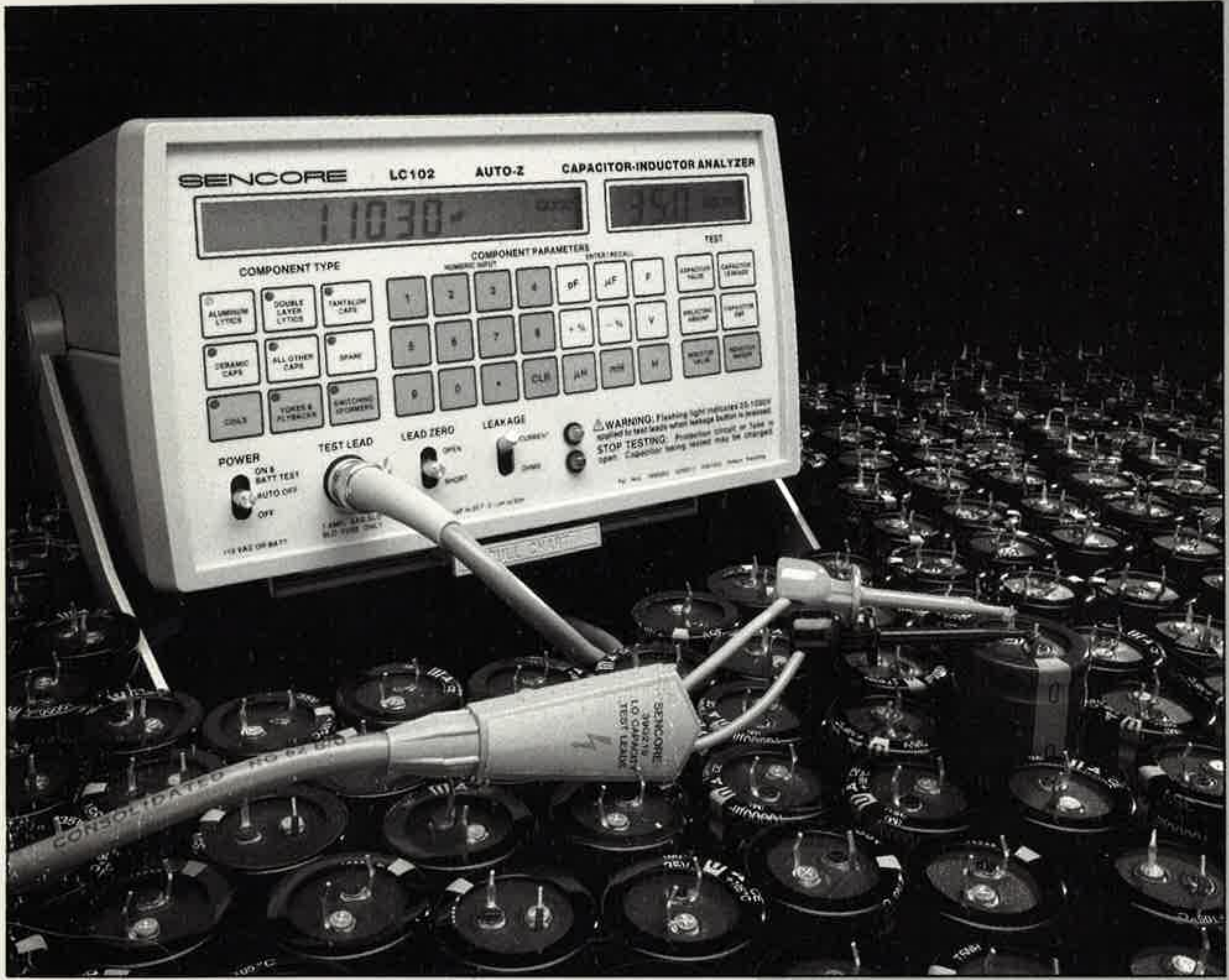
Servicer's Handbook Of Component Analyzing



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Servicer's Handbook Of Component Analyzing

Z-Meter Questions & Answers

SENCORE

3200 Sencore Drive, Sioux Falls, South Dakota 57107

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Introduction

Capacitors, inductors, and other special components play an integral part in all of our lives every day. Their operation affects what we see, hear, and do.

On the other hand, if one of these components fails in any way, it also affects our lives. One of these defective components can shut down a television set, prevent us from making a phone call, erase a block of computer memory, etc. In fact, these components are rarely noticed unless they become defective.

The challenge is finding these defective components and finding them fast. That's why Sencore designed the Z Meters. The patented Z Meters will find these bad components in a short amount of time, while keeping the tests simple.

Although the Z Meter tests may be short and simple, sometimes the readings will involve some interpretation, especially for non-standard components. This booklet is intended to help you interpret these tests on standard and non-standard components. It will help you identify what you are testing, what results to expect on the Z Meter, and why the Z Meter gives you these results. This booklet is not designed to replace the instruction manuals. You should read and fully understand the instruction manual before you attempt any test with the Z Meter.

The LC53 Z METER

- **First Analyzer To Test Caps And Coils.**
- **Tests Capacitors Dynamically Under Rated Voltage.**
- **Finds Bad Coils With Inductance And Ringing Tests.**
- **Z Meter Becomes The Industry Standard.**

Sencore introduced the first Z Meter in 1979, the LC53. The LC53 Z Meter was engineered to help technicians find bad capacitors, inductors, and some special components such as SCRs, triacs, high voltage diodes, and transmission lines.

The LC53 tests capacitors with three separate and dynamic tests: value, leakage, and dielectric absorption. Finally, the electronic industry had a method of finding bad capacitors other than using just a static value test.

The LC53 also includes the answers to inductor testing. First there is an inductor value test to help find value changes and opens. To find shorted inductors and inductors with even a single shorted turn, Sencore incorporated the ringing test into the LC53. If an inductor causes a circuit problem, the LC53 Z Meter can find it.

The LC75 Z METER 2

- **Assures You Of Finding Defective Capacitors And Inductors Other Testers Miss.**

- **Makes All Four Capacitor Tests (including ESR) To Find Even The Marginal Capacitors.**

- **Dynamic Inductance Tests Check For Value And The Coil's Ability To Work In-Circuit.**

- **Added Value Tests: Transmission Lines, SCRs, Triacs, Hi-Voltage Diodes.**

After years of Z Meter testing, Sencore's engineers found another capacitor defect that needed to be tested for, equivalent series resistance (ESR). Sencore added an ESR test to the LC75 plus updated and improved all of the existing tests for added reliability.

The Z Meter 2 gives you all four industry standard capacitor tests to gain confidence and save troubleshooting time. The LC75 checks capacitors for value from 1.0 pF to 200,000 uF, leakage up to 600 volts, dielectric absorption, and ESR, all with speed and accuracy.

The in- or out-of-circuit inductor tests are time-saving and 100% reliable. The LC75 finds the shorted turns the "value only" tester can't find.

The LC76 PORTA-Z

- **Full Day's Operation on Battery; Auto Shut Off After 30 Minutes**
- **Patented Capacitor Analyzer With Dynamic Leakage Tests to 1000 Volts**
- **Double Patented Inductor Analyzer**
- **LCD Display**
- **Tests L/C Components, SCRs, Triacs, Hi Voltage Diodes, Cables and Transmission Lines**
- **Rugged All Steel Construction**

The LC76 Porta-Z brought some new dimensions to the Z Meter line. It has the time-tested and proven features of capacitor and inductor analyzing in a portable package, eight hours on a single battery charge. The Porta-Z gives you the NIST (formerly NBS) traceable accuracy on the bench or in the field.

The LC76 locates capacitor failures other testers can't find. With an extended leakage range up to 1000 volts, the Porta-Z tests even the largest aluminum electrolytic capacitors.

With the new state-of-the-art power circuit, the LC76 gives you the capability of hi-pot testing up to 1000 volts anytime, anywhere.

The LC77 AUTO-Z

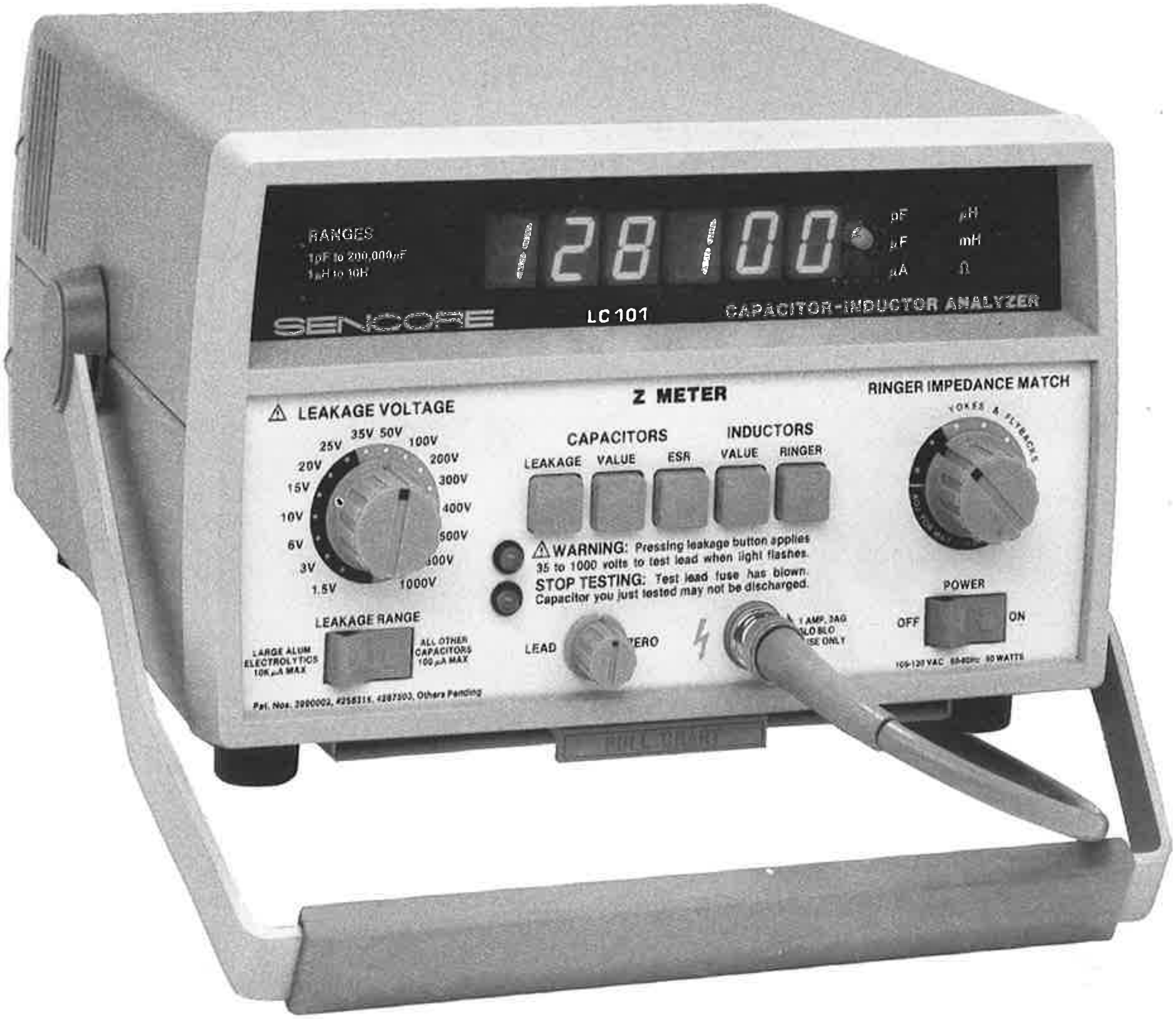
- **Automatic Ranging of Capacitance And Inductance Value**
- **Percentage Calculator**
- **Auto Shutoff & Battery Test**
- **Auto Lead Zero**
- **Leakage In Current and Ohms With Up To 1000 Volts Applied**
- **Dielectric Absorption And Equivalent Series Resistance (ESR)**
- **Inductor Ringing Test**
- **Good/Bad Determination**

The LC77 Auto-Z brings automatic testing to capacitor/inductor analyzing. The LC77 won't let you make a mistake since it's autoranged, autozeroed, and has an automatic shutoff feature to preserve battery life.

The Auto-Z truly tests for good or bad components. Since all of the parameter look-up tables are programmed in memory, you can enter in the component's value and tolerance and the LC77's LCD readout will display a good or bad reading. It's also IEEE 488 and RS232 Bus compatible to make volume testing faster and error-free, even with lower cost non-technical personnel.

The LC77 has extended capacitor and inductor measuring ranges to measure even the largest components you encounter. Hi-Pot testing has taken a turn for the better, too. With a flip of a switch, the Auto-Z converts the leakage current readings into a resistance reading.

The LC101 Z METER



- **Tests Capacitors For All Four Defects.**
- **Finds Defective Inductors Other Testers Miss.**
- **Special Tests: SCRs And Triacs, Transmission Lines, Hi-Voltage Diodes.**
- **Test Components Under Dynamic Conditions.**

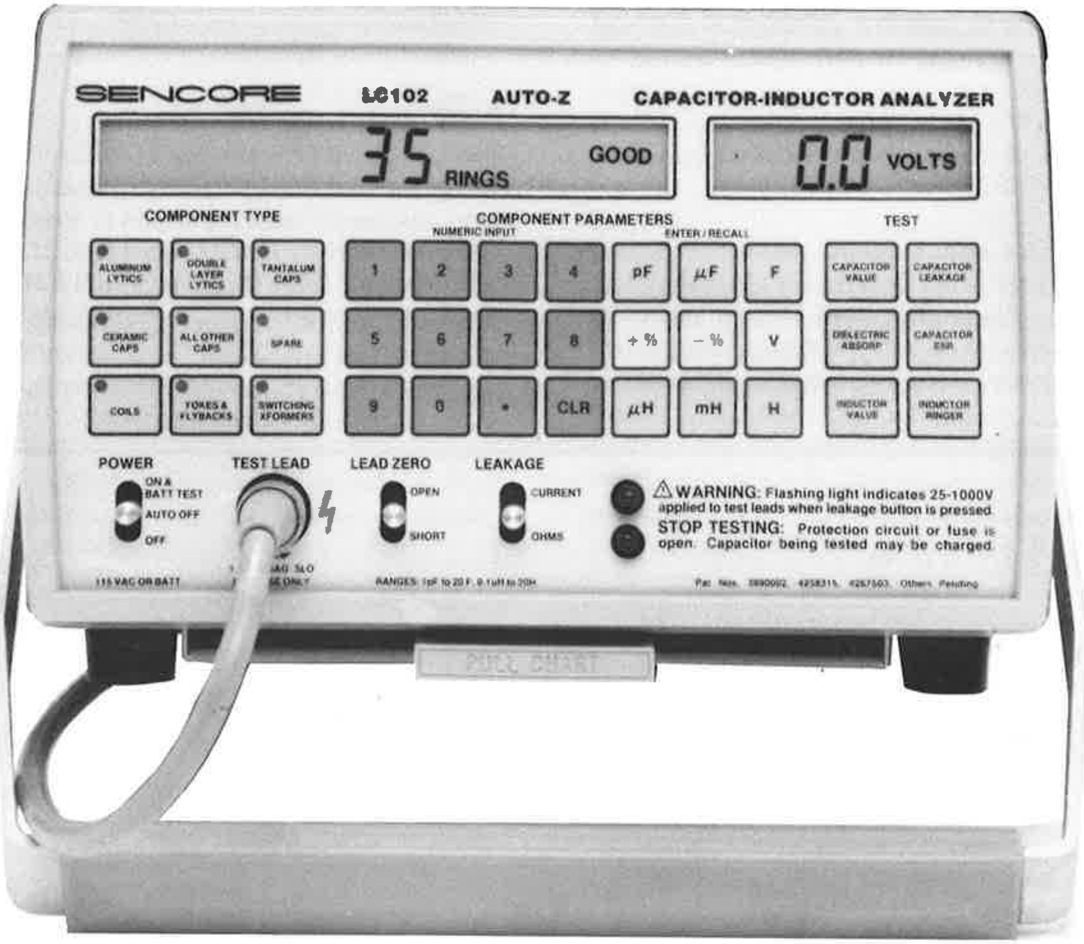
The LC101 Z Meter gives you all four industry standard capacitor tests to find even the marginal capacitors. The LC101 checks capacitors for value from 1.0 pF to 200,000 uF, leakage up to 1000 volts, dielectric absorption, and ESR, all with speed and accuracy.

The inductor tests can be performed in or out-of-circuit.

The LC101 finds shorted turns with the ringer test that "value only" testers can't find.

Audio and visual alert systems warn you if the LC101's internal discharge circuit fails or the test lead fuse blows. Protects you and your test instrument from charged capacitors.

The LC102 AUTO-Z



- Dynamic, Mistake-Proof, LC Analyzer That Finds Defective Components That All Other Testers Miss.

- Dynamically Tests Capacitors For:
  Value From 1 pF to 20 F
  Leakage With 1 kV Applied
  Dielectric Absorption
  Equivalent Series Resistance (ESR)

- Dynamically Tests Inductors From 1 uH To 20 Henrys For Opens, Shorts, Value, And Even One Shorted Turn.

- Dynamically Tests SCRs, Triacs, High Value Resistors, And Transmission Lines As An Added Bonus.

- Automatically Makes All Of The Tests, Compares Them To EIA (Electronic Industries Association) Standards And Reads The Results As Good Or Bad. Enter All Information Right From The Component.

- Extends Your Testing Capability To Places Where An AC Cord Won't Reach With Rechargeable 9 Hour Battery.

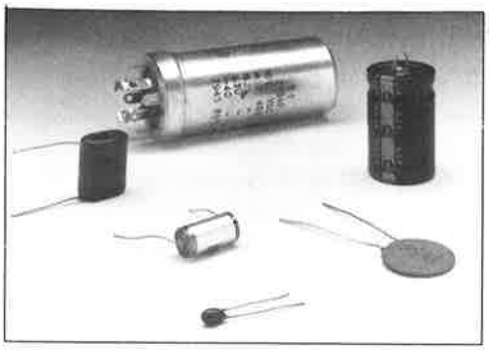
(Continued on page 12)

The LC102 is microprocessor controlled for speed and accuracy. Adds speed, reliability, and extended ranges to your cap/coil testing. Its advanced digital technology completely analyzes capacitors to 20 farads and inductors to 20 henrys. Simply enter the value, rated voltage, and tolerance and the AUTO-Z makes the readings, compares them to EIA tables stored in memory, and displays whether the component is good or bad. The push of a button gives you exact readings for value, leakage, dielectric absorption and equivalent series resistance (ESR).

Exclusive capacitor and inductor ranges measures capacitors from 1 pF to 20 farads, with leakage tests with up to 1000 volts applied, and ESR from 0.10 to 2000 ohms. Locates leakage (with .01 microamp resolution) in ceramic and tantalum capacitors that other testers can't find. Automatic ringing tests checks inductors, yokes, flybacks, and switching transformers with 100% reliability.

Audio and visual alert systems warn you if the AUTO-Z's internal discharge circuit fails or the test lead fuse blows. Protects you and your test instrument from charged capacitors.

Portability lets you use the LC102 in the shop, field, or factory. The LC102 packs full inductance, capacitance and resistance analyzing power into a light-weight, portable (battery and AC) package. It's designed with CMOS logic, LCD technology and automatic shut-off for long battery life (operates eight hours on a single charge).



Capacitors

The Capacitor

Quite simply, a capacitor consists of an insulator between two conductors that will store an electrical charge. Capacitance is the ability to store an electrical charge. However, the charge must be applied by some voltage source. In figure 1, the battery in the simple series circuit can charge the capacitor shown. The capacitor will charge until the potential across it equals the battery voltage. Since a capacitor is a voltage storage device, the battery charge will remain on the capacitor even after the battery is removed from the circuit. Figure 2 shows the most common schematic symbol for capacitors, also known by the old name of condensers.

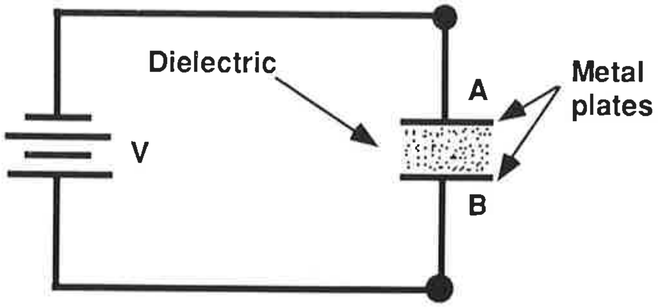


Fig. 1: Capacitance stores charge in the dielectric between two conductors.

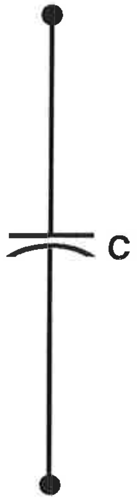


Fig. 2: Schematic symbol for a capacitor.

When a capacitor is connected to a voltage source, it does not become fully charged instantaneously, but takes a definite amount of time. The time required for the capacitor to charge is determined by the size or capacity of the capacitor, and the resistor in series with the capacitor or the voltage source's own internal series resistance. This is called the RC time constant. Capacity in farads multiplied by resistance in ohms equals the RC time constant in seconds. The rate of charge of the capacitor is the RC charge curve (figure 3). The capacitor is considered completely charged in five time constants.

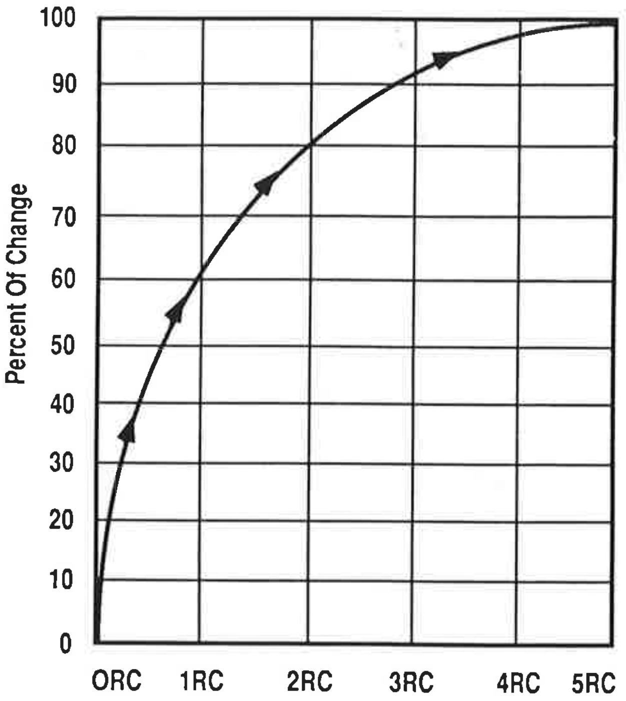


Fig. 3: Capacitors follow an RC charge time as they charge to the applied voltage.

The Units Of Capacitance: Farad, uF, And pF

The unit for capacitance is the farad (F), named after Michael Faraday. When one coulomb is stored in the dielectric with a potential difference of one volt, the capacitance is one farad. Since the farad is such a large amount of capacitance, however, most capacitors are labeled in the uF or pF range. These common capacitance units are represented by the following numbers:

Change to → From ↓	Farads F	Micofarads uF	Nanofarads nF	Picofarads pF
Farads F		move decimal 6 places right	move decimal 9 places right	move decimal 12 places right
Microfarads uF	move decimal 6 places left		move decimal 3 places right	move decimal 6 places right
Nanofarads nF	move decimal 9 places left	move decimal 3 places left		move decimal 3 places right
Picofarads pF	move decimal 12 places left	move decimal 6 places left	move decimal 3 places left	

Fig. 4: Capacitor value conversion chart.

$$\mathbf{1\ microfarad = 1\ uF = 1 \times 10^{-6}\ F}$$
$$\mathbf{1\ picofarad = 1\ pF = 1 \times 10^{-12}\ F}$$

Some manufacturers have different methods of marking the capacitor's value on the capacitor. For example, one manufacturer may mark a capacitor "3300 pF", yet another manufacturer may mark an identical replacement as ".0033 uF". By converting and moving decimal places as shown in the chart in figure 4, the two capacitors come out to be the exact same value.

Capacitor Defects

An ideal capacitor is defined as "a device consisting of two electrodes, separated by a dielectric, for introducing capacitance into an electric circuit." Unfortunately, we don't work with ideal components. The capacitors we encounter every day in our service work are much more complex than this simple definition. In an actual capacitor, a certain amount of current leaks through the dielectric or the insulation. Capacitors have internal series resistances, can exhibit an effect called dielectric absorption, and the capacitance can change in value. If we were to draw a circuit to represent an actual capacitor, it might look like the circuit in figure 5.

The capacitor C1 represents the true capacitance, the resistance Rp represents the leakage path through the capacitor, and resistance Rs, called the Equivalent Series Resistance (ESR), represents all of the combined internal series resistances in the capacitor. If any one or more of these parameters change value, the capacitor will not perform normally. These abnormalities can be classified into four different capacitor failure modes: value change, leakage, dielectric absorption, and ESR.

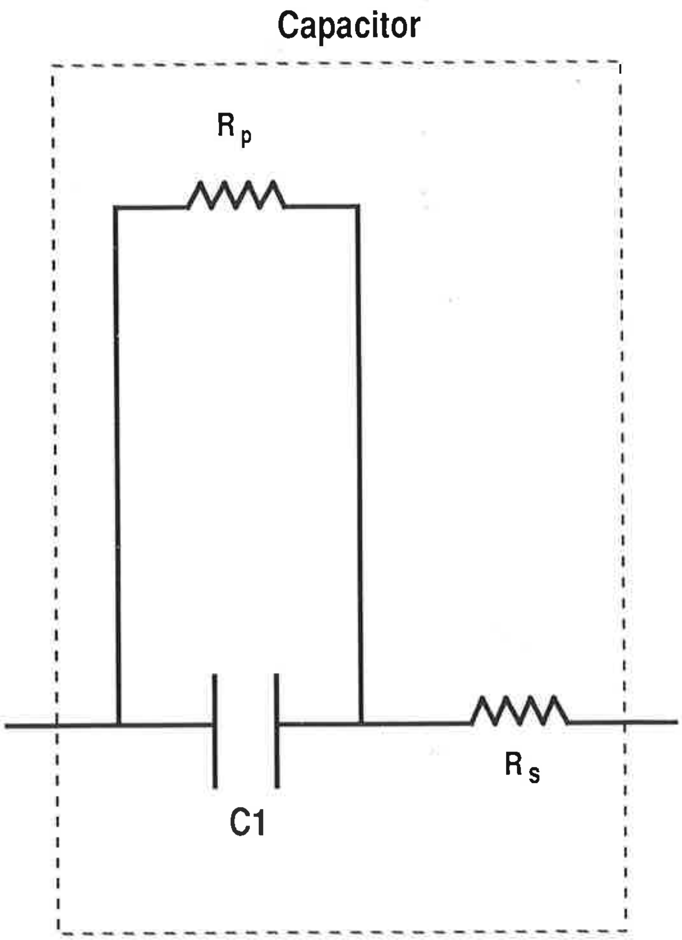
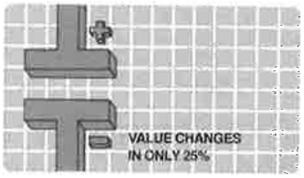


Fig. 5: Equivalent circuit of a practical capacitor.

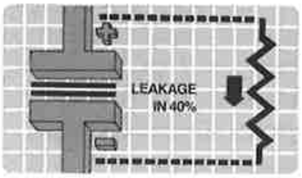
Value Change



Twenty-five percent of all defective capacitors are related to value change. On some multi-layer foil capacitors, poor welding or soldering of the foil to the leads can cause an open to one of the foils to develop due to stress of voltage or temperature. This can result in a loss of almost one-half of the capacitor's marked capacity. Ceramic disc capacitors can also change value due to fissures or cracks. Small fissures or cracks in the ceramic insulating material can be created by thermal stress from exposure to heat and cold.

Sometimes very small fissures develop which do not affect the capacitor until much later. The crack will reduce the capacitor to a smaller value. Although the ceramic is still connected to the leads, the actual value of capacity could be a very small portion of the original value depending upon where the crack occurs.

The electrolytic capacitor is another example of a capacitor that can change value in circuit or on the shelf. As these capacitors dry out, they eventually lose their capacitance due to the failure of the aluminum oxide film making up the dielectric. A change in value in an aluminum electrolytic will often also be preceded by other defects, such as high leakage, high dielectric absorption and/or high internal resistances.



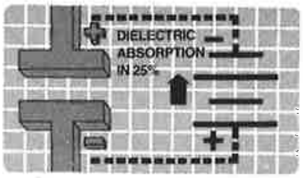
Leakage

The most common capacitor failure is caused by current leaking through the capacitor; over 40% show this defect. Some capacitors will show a gradual increase in leakage with age, while others will change rapidly and even short out entirely. Leakage is not always proportional to the voltage applied, either. For example, a 450 volt capacitor may not have any leakage characteristics at all until there are 250 volts across it.

When a DC voltage is applied to a capacitor, a certain amount of current will flow through the capacitor. This current is called the leakage current and is the result of imperfections in the dielectric. Leakage, however, is a normal condition of electrolytic capacitors.

Whenever this leakage current flows through an electrolytic capacitor, normal chemical processes take place to repair the damage done by the current flow. Heat will be generated from the leakage current flowing through the capacitor and will speed up the chemical repair processes.

As the capacitor ages, the amount of water remaining in the electrolyte will decrease, and the capacitor will be less capable of healing the damage done by the various leakage paths through the dielectric. Thus, as the amount of water in the electrolyte decreases, the capacitor will be less capable of healing the leakage paths and the overall leakage current in the capacitor will ultimately increase. The increase in leakage current will generate additional heat, which will speed up the chemical processes in the capacitor. This process, of course, will use up more water and the capacitor will eventually go into a run-away mode. At some point, the leakage current will finally get large enough to adversely affect the circuit the capacitor is used in.



Dielectric Absorption (DA)

Dielectric absorption (DA) is one of the most common types of failures of electrolytic capacitors. Twenty-five percent of all defective capacitors contain some form of dielectric absorption.

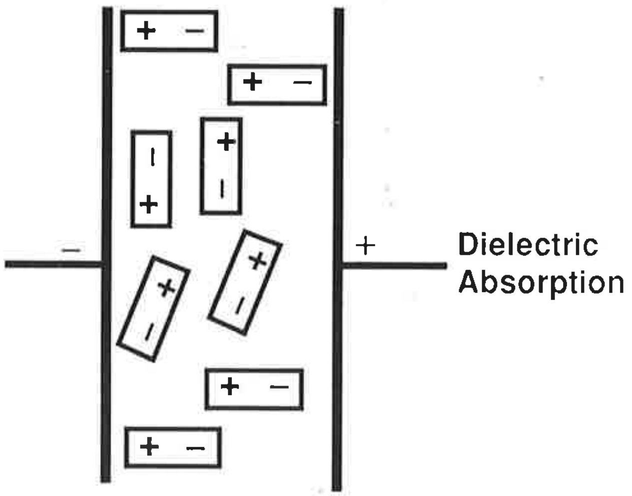
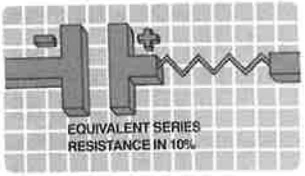


Fig. 6: Dielectric absorption is the result of the dielectric's dipoles remaining in a polarized state after discharging. This will cause poor filtering and distorted waveforms in the circuit.

Dielectric absorption is the inability of a capacitor to release all its stored energy, even if a dead short is applied across its leads. The condition is due to some of the dipoles in the dielectric material remaining in a polarized position rather than fully releasing the potential energy that is stored when the capacitor is charged.

Some people refer to the effects of dielectric absorption as "battery action" because a voltage reappears on the capacitor a short time after the capacitor has been discharged. An extremely bad capacitor may recover as much as 50% of the original voltage after the capacitor has been discharged and allowed to sit for a 24-hour period.

Some circuits are directly affected by the effects of dielectric absorption. The biggest effects are in circuits that use a capacitor to hold a precise DC level. Three of the most common circuit problems caused by dielectric absorption are: 1. Inaccurate voltage levels when the capacitor is used in a DC application such as a sample and hold circuit, 2. Increased ripple in power supplies, 3. Distortion when the capacitor is used as a coupling (DC blocking) capacitor.



Equivalent Series Resistance (ESR)

Another problem which develops in capacitors is high equivalent series resistance (ESR). ESR is present in all capacitors, but is not a problem until it exceeds the specifications of the capacitor.

Problems with ESR have increased in the past few years due to increased use of the aluminum electrolytic capacitor. Although ESR comprises less than 10% of all capacitor defects, and is almost always in aluminum electrolytics, it causes real problems in todays high current, high frequency circuits.

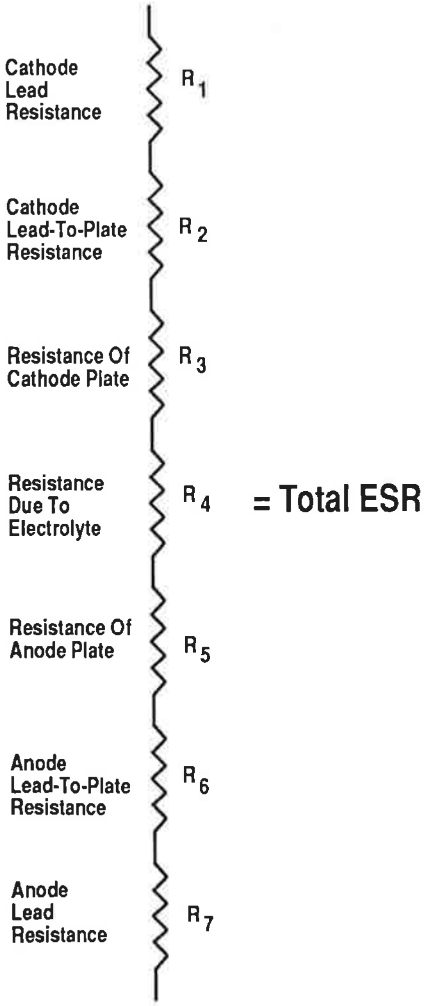


Fig. 7: The ESR of a capacitor is composed of all the combined internal resistances in the capacitor.

As figure 7 shows, ESR is the electrical resistances in series with the capacitor plates. This includes the resistance of the metal leads, the plates, all connection resistances, and the losses associated with the dielectric. Normal amounts of ESR are tolerated by the capacitor and the circuit it is used in. Any increases in ESR, however, can affect the circuit in which the capacitor is used, as well as the capacitor itself.

A capacitor with ESR is equivalent to a resistor in series with the capacitor in circuit. ESR will rob power from the circuit and hinder its normal performance. Current flows through the excessive resistance inside of the capacitor and produces heat. The heat is a wasted form of power plus it accelerates the aging process of the capacitor causing it to fail prematurely. Other problems caused by excessive ESR are: changed time constant, less filtering capability, upset DC biases, etc.

Z METER Capacitor Tests

Sencore's Z Meters test for the four different things that go wrong with capacitors. The Z Meter checks them according to Electronic Industry Standards and checks them dynamically with full potential applied. The Z Meter tests are patented five times over, so these tests will not be found anywhere else.

Capacitor Value

- **DC-Time Constant Method.**
- **Autoranged.**
- **Value Normally Goes Down.**
- **Aluminum Electrolytic Value Increase May Be A Sign Of Other Problems.**
- **Blank, Flashing 8's, or 1— indicates high level of DA.**

Z Meters find capacitor value by measuring the time needed to charge the unknown capacitor through a precision resistor. The time-constant calculates into a capacitor value. This resultant value reading displayed by the Z Meter is the most accurate reading possible because it shows how the capacitor works in DC circuits.

Once the Z Meter has calculated the capacitance value, it autoranges it and displays it in pF, uF, or F without any lookups, calculation, interpretation, or range switching. The Z Meter reads the actual capacitance at

DC, so if the Z Meter's reading does not fall within the tolerance of the capacitor, the capacitor is bad.

Capacitors rarely exhibit an increase in capacitance value. As aluminum electrolytics age, they may show an increase in value, but the increase in value is a sign of other problems in the capacitor, such as ESR. In any case, a capacitor that does not fall within the normal tolerances of a capacitor should be considered bad and should be replaced.

If a capacitor changes value, the value usually goes down, or even opens up. When a capacitor's value drops, such as is the case when an electrolytic's dielectric solution dries out, the filtering or storage capability also drops, rendering the capacitor useless.

An open capacitor will test similarly to an open set of leads on a properly zeroed Z Meter. The capacitance value test will yield a value of something near 0 pF. When you read the capacitance value on open leads, the value is approximately 0 pF. It only stands to reason that a 0 pF reading on a capacitor means that the capacitor is open.

Occasionally, a capacitor will give you an abnormal reading on the Z Meter's display. Among these readings are flashing 8's, a blanked out display or a 1 followed by blank spaces. These readings indicate a problem with the capacitor, usually an abnormally high amount of leakage, dielectric absorption, ESR, or a combination of these. The abnormal readings indicate that the Z Meter is searching for a capacitance range to lock onto, but the defective capacitor is causing the Z Meter to change ranges constantly. Z Meters are designed to display these unusual readings when they test defective capacitors like these.

Comparing A Meter Capacitor Value To Bridge Readings

- **Bridge Measures Capacitance Reactance, Xc.**
- **Test Is Frequency Dependent.**
- **South Dakota State University Research Confirms Z Meter Method.**
- **Z Meter Values Vary Directly With Capacitor Tolerance.**

Some capacitors read differently from their capacitor value on a Z Meter compared to a bridge. Neither reading is wrong, they're just a result of two different methods of measurement.

The Z Meters measure the capacitance value by charging the capacitor through a precision resistor and calculating the time constant. Since this measurement is effectively made at DC, the readings are not frequency selective.

A bridge, on the other hand, actually measures the capacitive reactance, Xc, of a capacitor. Bridges apply a frequency to the capacitor (usually 120 Hz or 1 kHz) and measure the reactance at that frequency. The formula for capacitive reactance is:

$$Xc = 1/2 \pi fc$$

Since the "f" in the formula stands for frequency, any capacitor that is frequency dependent, will measure differently on a bridge compared to a Z Meter. In fact, a capacitor's value will read differently on a 120 Hz bridge compared to a 1 kHz bridge.

Electrolytic capacitors, especially, are frequency selective capacitors. This type of capacitor will probably show a higher value than its marked value with a Z Meter. The DC test method usually shows an electrolytic capacitor to have a value higher because the electrical properties of the water inside the capacitor change with frequency.

SDSU Capacitor Value Research Results

South Dakota State University ran a study to understand the relationship between capacitance as measured by the Sencore "Z Meters" and that measured by other methods. The following is an excerpt from the study:

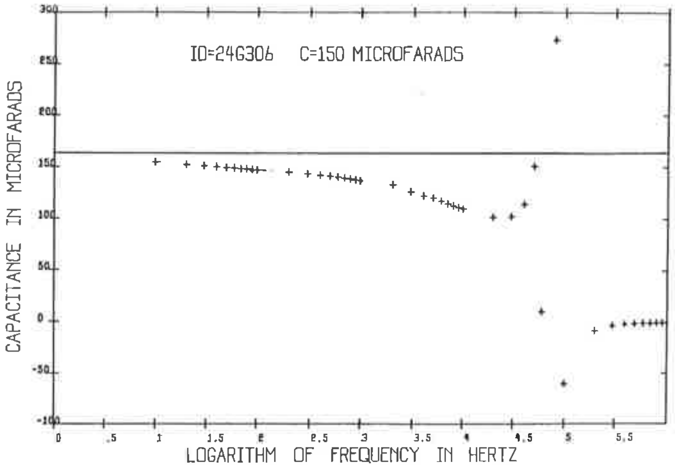


Fig. 8: Comparison of capacitance values for an electrolytic capacitor measured with an HP 4192A as a function of frequency and the value measured using a Sencore LC53 "Z-Meter". The solid line represents the Z-Meter value.

"The capacitance of a typical electrolytic capacitor as measured by a bridge method varies with frequency as shown in figure 8. Comparing these values with the Z Meter reading shows low-frequency bridge values to be slightly less than the Z Meter value. They decrease until a resonance is reached which leads to a large positive increase followed by negative values. This behavior is contrasted with data shown in figures 9 and 10 for a ceramic disk capacitor and a mylar capacitor. Neither of these exhibit a significant drop in capacitance with frequency although the mylar capacitor does display the resonance.

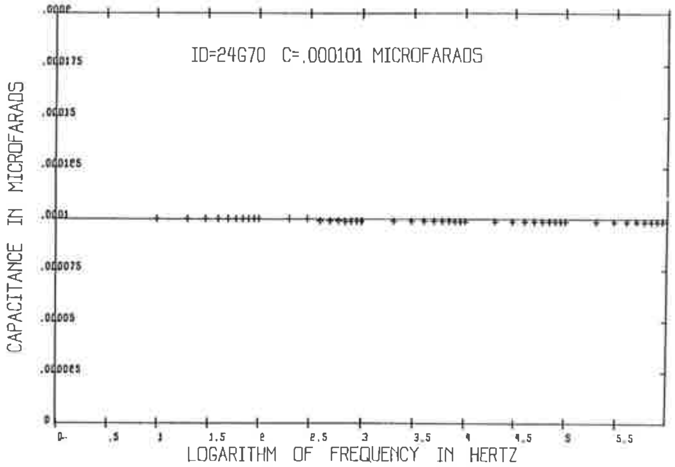


Fig. 9: Comparison of capacitance values for a ceramic disk capacitor measured with a HP 4192A as a function of frequency and the value measured using a Sencore LC-53 "Z Meter". The solid line represents the Z-Meter value.

.....The decrease in capacitance with frequency has not been uniquely determined. However, the most probable cause is the motion of the water molecule dipoles on the anode of the capacitor. To understand the process involved, one must consider the construction of the electrolytic capacitor as shown schematically in figure 11.

The AL_2O_3 is the insulating layer which prevents the flow of current. Thus the leakage current characteristics are determined by this layer. The layer of hydrated oxide ($AL_2O_3 \bullet H_2O$) is formed intentionally to increase a higher dielectric constant and thus a higher capacitance (Bernard, 1977). Even if the hydrated oxide is not intentionally formed, water is always present due to a chemical reaction between the ethylene glycol and ammonium borate or other conductive salts usually used as an electrolyte (Bernard, 1977).

....The components in an electrolytic capacitor that affect the overall dielectric constant are the aluminum oxide layer, the hydrated oxide layer, the electrolyte, and the paper spacer. These components can vary for different capacitors, including solid electrolytes. Dielectric constants for the aluminum oxide, ethylene glycol, and water, treated separately are constant at the frequencies far beyond these considered in the data (Von Hippel, 1954).For aqueous electrolytes the frequency where the dielectric constant starts to drop is approximately 10^{10} XM; where M is the molarity of the solution (Hasted, 1973). It is not known what molarity the electrolyte solutions are, but they would have to be extremely small to have any effect on the dielectric constant.

The paper spacer is most likely not frequency dependent, but even if it were, it has a small dielectric constant and will not appreciably affect the total dielectric constant. Water molecules, however, are known to give a relaxation frequency in the one kilohertz region (Hasted, 1973). Since the relaxation frequency is the frequency at which the molecules cannot follow the alternation electric field, this would result in a drop of the dielectric constant in the observed frequency range....

Conclusions

Results of this project indicate that values of capacitance measured by different methods arise primarily from two factors. These factors are the equivalent series resistance (ESR) and the frequency dependence of the dielectric constant of the hydrated aluminum oxide layer present in the capacitor.

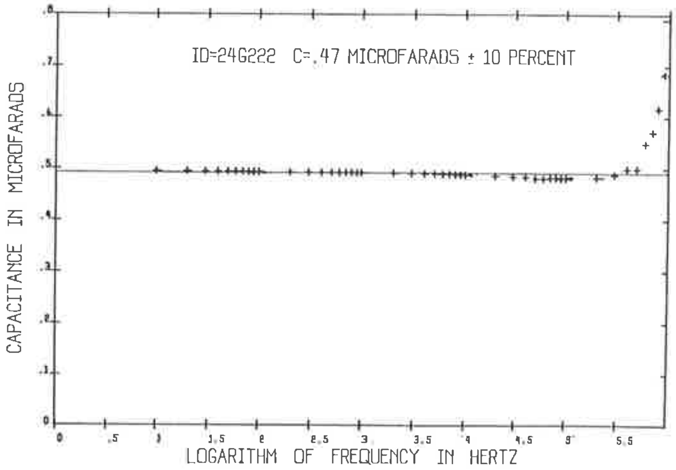


Fig. 10: Comparison of capacitance values for a mylar-foil capacitor measured with an HP 4192 A as a function of frequency and the value measured using a Sencore LC53 "Z Meter". The solid line represents the Z-Meter value.

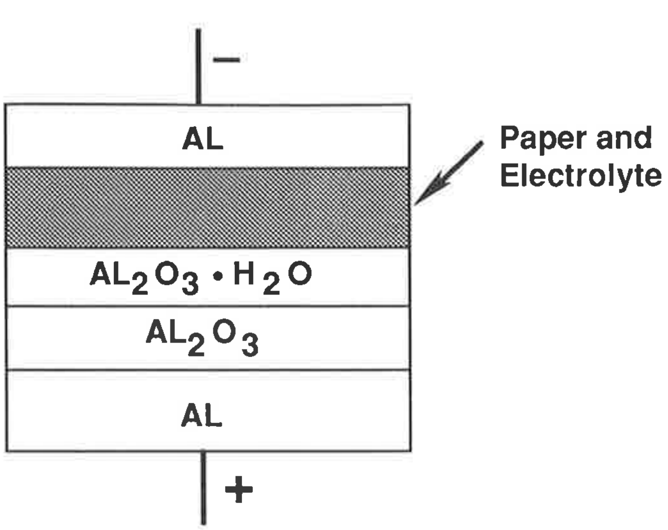


Fig. 11: Schematic diagram of the construction of an electrolytic capacitor.

Any balanced bridge or phase method which measured capacitance using the AC signal measures a value which is valid only for the measurement frequency. This fact has been demonstrated by this research since the dielectric constant was found to decrease with frequency until it reaches a resonance point."

Since most capacitor manufacturers test the electrolytic capacitor with a 120 Hz or 1 kHz bridge, electrolytic capacitors are often marked with lower value than the value at DC. The DC Z Meter test shows the correct, higher value that the capacitor produces in a DC circuit. (The SDSU report is available upon request.)

Applying The Manufacturer's Tolerance

Unfortunately, the readings between Z Meters and bridges are not able to be converted to one another by a mathematical formula. A conversion is not possible because "the relaxation time would be dependent on the amount of water and the specific components of the capacitor" which are not published.

This conversion is not necessary, however, if the manufacturer's tolerance of the capacitor is applied to the Z Meter's reading. The SDSU research and Sencore's engineers' tests indicate that the manufacturer's tolerance is directly related to the frequency dependent value readings. A Z Meter will read a good 20 percent capacitor within 20 percent of the marked value even if it is not the same as a bridge reading. An 80 percent capacitor, however, may read further from its marked value with a Z Meter, but still within 80 percent. A capacitor whose Z Meter value readings don't fall within tolerance should be considered bad

Questions & Answers

Can the Z Meter test a capacitor's value in-circuit?

No. The Z Meter or any other tester cannot accurately measure capacitor value or any other capacitor parameter in-circuit. The circuit adds too many variables and parallel impedance paths for accurate readings.

You can lift one side of a capacitor and measure the value with one side still in circuit, however. Be sure to connect the Z Meter's black lead to the circuit side of the capacitor to prevent parallel impedances from upsetting the readings.

Can I test capacitor value while the push rod is holding in the capacitance value button?

We never recommend this test procedure to anyone for two reasons. First, the Z Meter automatically discharges any capacitor as soon as you hook up the leads to it. It also discharges the capacitor when you are through with each Z Meter test. By having the CAPACITANCE VALUE button pushed in, the capacitor discharge circuits are disabled, therefore the capacitor will never have a chance to discharge. A charged capacitor poses a potential shock hazard to anyone who comes in contact with the capacitor until it is discharged.

Secondly, Z Meters are equipped with safety protection circuits to protect the capacitance value circuits from receiving an excessive amount of voltage. If the CAPACITANCE VALUE button is held in while a charged capacitor is being hooked up to the leads, the protection circuits are bypassed and the voltage present on the capacitor will be routed to the measuring circuits. This external voltage may cause damage to the Z Meter's circuits.

How do I measure the very small value capacitors?

The resolution of Z Meters on small capacitors goes all the way down to 0.1 pF, so just pushing the CAPACITANCE VALUE button on a properly zeroed Z Meter and reading the value will usually suffice.

However, if you need a more precise capacitance reading, especially on capacitors under 1 pF, you may want to use a parallel combination of capacitors and calculate the capacitance. For example, if you wanted to measure the actual capacitance value of a 0.7 pF capacitor, you simply start by measuring a larger capacitor, such as 10 pF, and noting the value (10.1 pF in this case). Now, put the 0.7 pF capacitor in parallel with the 10 pF capacitor and measure the total capacitance value with the Z Meter. Since parallel capacitances add, if the value of the two capacitors in parallel read 10.9 pF, you take that reading and subtract the value of the 10 pF capacitor, which was 10.1 pF. The result, 0.8 pF, is the actual value of the unknown capacitor.

Leakage

- **Z Meter Tests At Rated Voltage.**
- **The More Leakage, The Worse The Capacitor.**
- **Leakage Current Must Be Less Than Maximum Limit.**
- **No Need To Wait For Zero Leakage Reading.**

Capacitor leakage occurs when some of the voltage from one plate flows (leaks) through the dielectric to the other plate. The amount of leakage current through the dielectric depends on the voltage applied across the plates. THE MORE LEAKAGE THE CAPACITOR HAS, THE WORSE IT IS. For this reason, the Z Meter tests capacitor leakage at the capacitor's rated voltage.

The Z Meter applies the rated voltage, which you have chosen, to the capacitor when you push the LEAKAGE pushbutton. The capacitor's resultant leakage is displayed as a current on the Z Meter's display. The maximum allowable leakage current is determined by the type of capacitor, the capacitance value, and the voltage rating of the capacitor. If the capacitor has more leakage than the maximum allowable leakage, it is bad.

Most capacitors will have little or no leakage. Tantalum and aluminum electrolytics, however, all have some normal allowable leakage. The maximum allowable leakage levels, as specified by the EIA (Electronic Industry Association), are shown in the Z Meter's pull charts, instruction manuals, and figures 13 and 14.

As long as the Z Meter leakage reading is less than the value listed in the reference table, the capacitor is good. If the Z Meter leakage reading is more than the value listed in the reference table, however, the capacitor is bad and should be replaced.

You do not need to wait for the leakage readings to drop to zero or to its lowest point. The capacitor is good for any leakage reading which is lower than the amount shown in the chart.

Leakage values shown in the charts for aluminum electrolytic capacitors are the worst-case conditions, as specified by the EIA standard RS-395. The values are determined by the formulas: L = 0.05xCV (for CV products less than 1000) or L = 6 x square root of CV (for CV products greater than 1000). (The CV product is equal to the capacitance value multiplied by the voltage rating.)

The tantalum capacitor leakage values listed in figure 13 are for the most common type of tantalum capacitors - dipped solid, type 3.3. These values are specified by EIA standard RS-228B, following the formula : L = -.35 x square root of CV. In a few applications outside of consumer service, tantalum capacitors other than type 3.3 may be encountered. Refer to the manufacturer's specifications for the maximum allowable leakage for these special capacitor types.

Capacitor Leakage Charge Time

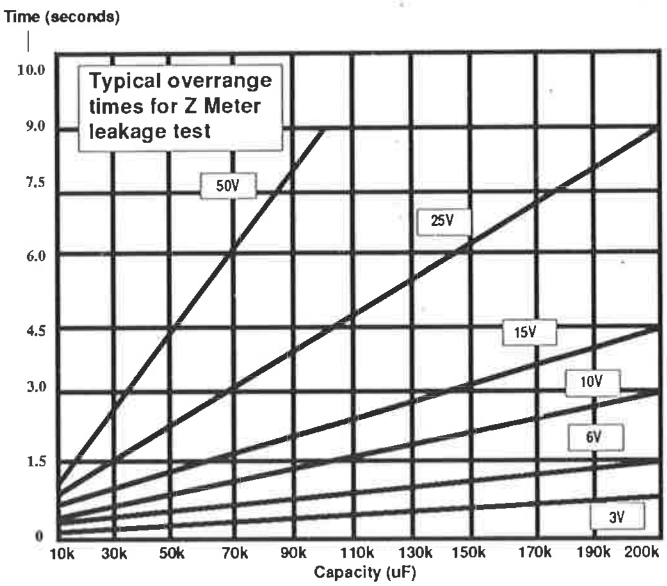


Fig. 12: Z Meter overrange time versus capacitor value and applied voltage.

Because of their larger value and higher leakage characteristics, aluminum electrolytic capacitors may take several seconds to charge. The Z Meter display may overrange (flashing 8's) while the capacitor is charging, indicating a large charging current. Figure 12 shows the approximate time that you can expect the Z Meter to overrange for a given capacitor value and applied voltage.

After the Z Meter stops overranging, the current will drop in progressively smaller steps as the capacitor charges. When the capacitor is fully charged, the leakage readings will change just a few digits up or down. You do not need to wait until an electrolytic capacitor is fully charged to determine if it is good. Simply keep the CAPACITOR LEAKAGE button depressed until the leakage reading falls below the maximum amount shown in the leakage tables. If the Z Meter readings stabilize off at a level that is higher than the maximum allowable leakage level, the capacitor is bad.

Maximum Allowable Leakage (in Microamps)

Dipped Solid Tantalum Capacitors

Capacity	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.5	4.9	6.1	7.0	7.8	8.6	11
1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	2.0	4.3	6.1	7.4	8.6	9.6	11	14
2.2	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.2	2.0	5.2	7.3	9.0	10	12	13	16
3.3	1.0	1.0	1.0	1.0	1.0	1.5	2.2	2.0	3.0	6.4	9.0	11	13	14	16	20
4.7	1.0	1.0	1.0	1.0	1.5	2.0	2.6	2.5	3.5	7.6	11	13	15	17	19	24
6.8	1.0	1.0	1.0	1.5	2.0	2.5	3.0	3.0	6.5	9.1	13	16	18	20	22	29
10	1.6	1.6	1.6	2.0	2.5	3.0	4.0	5.0	7.8	11	16	19	22	25	27	35
15	2.2	2.2	2.2	2.5	3.0	4.0	7.0	5.0	9.6	14	19	23	27	30	33	43
22	2.8	2.8	2.8	3.0	5.0	9.5	10	10	12	16	23	28	33	37	40	52
33	3.4	3.4	3.4	5.0	7.5	15	10	11	14	20	28	35	40	45	49	64
47	4.0	4.0	4.0	10	10	15	15	16	17	24	34	42	48	54	59	76
68	5.0	5.0	5.0	15	15	20	15	17	20	29	41	50	58	65	71	91
100	10	10	10	15	20	20	17	21	25	35	49	61	70	78	86	111
150	15	15	15	20	20	19	21	25	30	43	61	74	86	96	105	136
220	20	20	20	20	20	23	26	31	37	52	73	90	104	116	127	164
330	20	20	20	20	25	28	32	38	45	64	90	110	127	142	156	201
470	24	24	24	24	29	34	38	45	54	76	107	131	152	170	186	240
680	29	29	29	29	35	41	46	54	65	91	129	158	183	204	224	289
1000	35	35	35	35	43	49	55	65	78	111	157	192	221	247	271	350
1500	43	43	43	43	53	61	68	80	96	136	192	235	271	303	332	429
2200	52	52	52	52	64	73	82	97	116	164	232	284	328	367	402	519
3300	64	64	64	64	78	90	101	119	142	201	284	348	402	450	492	636
4700	76	76	76	76	93	107	120	142	170	240	339	416	480	537	588	759
6800	91	91	91	91	112	129	144	171	204	289	408	500	577	645	707	913
10000	111	111	111	111	136	157	175	207	247	350	495	606	700	783	857	1107
15000	136	136	136	136	166	192	214	254	303	429	606	742	857	959	1050	1356
22000	164	164	164	164	201	232	260	307	367	519	734	899	1038	1161	1272	1642
33000	201	201	201	201	246	284	318	376	450	636	899	1101	1272	1422	1557	2011
47000	240	240	240	240	294	339	379	449	537	759	1073	1314	1518	1697	1859	2399
68000	289	289	289	289	353	408	456	540	645	913	1291	1581	1825	2041	2236	2886
100000	350	350	350	350	429	495	553	655	783	1107	1565	1917	2214	2475	2711	3500
150000	429	429	429	429	535	606	678	802	959	1356	1917	2348	2711	3031	3320	4287
200000	495	495	495	495	606	734	783	971	1100	1570	2210	2710	3130	3500	3830	5191

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Fig. 13: Maximum allowable leakage for solid tantalum electrolytics per EIA standards.

Maximum Allowable Leakage (in Microamps)

Standard Aluminum Electrolytic Capacitors

Capacity in uF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	5	5	5	5	5	5	5	5	5	5	10	15	20	25	30	50
1.5	5	5	5	5	5	5	5	5	5	8	15	23	30	38	45	232
2.2	5	5	5	5	5	5	5	5	6	11	22	33	44	199	218	281
3.3	5	5	5	5	5	5	5	6	8	17	33	50	218	244	267	345
4.7	5	5	5	5	5	5	6	8	12	23	47	225	260	291	319	411
6.8	5	5	5	5	5	7	9	12	17	34	221	271	313	350	383	495
10	5	5	5	5	8	10	13	18	25	50	268	329	379	424	465	600
15	5	5	5	8	11	15	19	26	38	232	329	402	465	520	569	735
22	5	5	7	11	17	22	28	39	199	281	398	487	563	629	689	890
33	5	5	10	17	25	33	41	204	244	345	487	597	689	771	844	1090
47	5	7	14	24	35	47	206	243	291	411	582	712	823	920	1008	1301
68	5	10	20	34	192	221	247	293	350	495	700	857	990	1106	1212	1565
100	8	15	30	50	232	268	300	355	424	600	849	1039	1200	1342	1470	1897
150	11	23	45	232	285	329	367	435	520	735	1039	1273	1470	1643	1800	2324
220	17	33	218	281	345	398	445	526	629	890	1259	1541	1780	1990	2180	2814
330	25	50	267	345	422	487	545	645	771	1090	1541	1888	2180	2437	2670	3447
470	35	225	319	411	504	582	650	770	920	1301	1840	2253	2602	2909	3186	4113
680	192	271	383	495	606	700	782	926	1106	1565	2213	2710	3129	3499	3832	4948
1000	232	329	465	600	735	849	949	1122	1342	1897	2683	3286	3795	4243	4648	6000
1500	285	402	569	735	900	1039	1162	1375	1643	2324	3286	4025	4648	5196	5692	7348
2200	345	487	689	890	1090	1259	1407	1665	1990	2814	3980	4874	5628	6293	6893	8899
3300	422	597	844	1090	1335	1541	1723	2039	2437	3447	4874	5970	6893	7707	8443	
4700	504	712	1008	1301	1593	1840	2057	2434	2909	4113	5817	7125	8227	9198		
6800	606	857	1212	1565	1916	2213	2474	2927	3499	4948	6997	8570	9895			
10000	735	1039	1470	1897	2324	2683	3000	3550	4243	6000	8485					
15000	900	1273	1800	2324	2846	3286	3674	4347	5196	7348						
22000	1090	1541	2180	2814	3447	3980	4450	5265	6293	8899						
33000	1335	1888	2670	3447	4221	4874	5450	6448	7707							
47000	1593	2253	3186	4113	5038	5817	6504	7695	9198							
56000	1739	2459	3478	4490	5499	6350	7099	8400								
68000	1916	2710	3832	4948	6060	6997	7823	9256								
100000	2324	3286	4648	6000	7348	8485	9487									
150000	2846	4025	5692	7348	9000											
220000	3447	4874	6893	8899												

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Fig. 14: Maximum allowable leakage for aluminum electrolytics per EIA standards.

Tantalum electrolytic capacitors have much lower leakage than aluminum electrolytics of the same size and voltage rating. Therefore, tantalum lytics will give a leakage reading in a much shorter time than an aluminum lytic - typically within 2 to 5 seconds.

Polarity

Polarity is only important for the Z Meter leakage test on aluminum and tantalum electrolytics. You will not achieve proper leakage readings unless the Z Meter's red clip is connected to the positive (+) terminal and the black clip is connected to the negative (-) terminal. Reversing the Z Meter's leads will yield bogus leakage readings and may damage the capacitor under test.

Questions & Answers

What voltage should I use if the capacitor's voltage falls between two Z Meter leakage voltages?

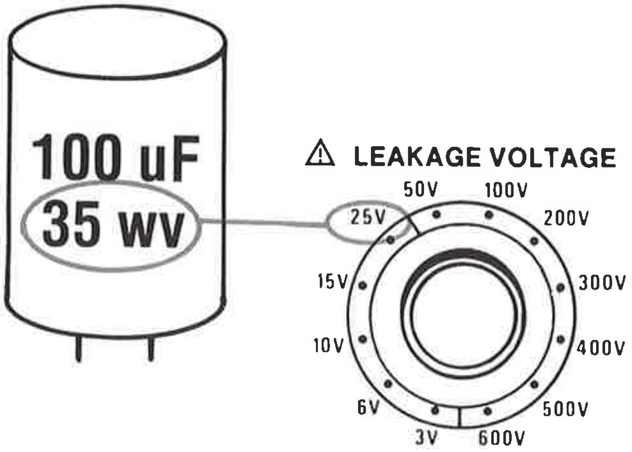


Fig. 15: Always use the next lower voltage if the capacitor's working voltage falls between two Z Meter voltage steps.

Always use a voltage which is UNDER the rated voltage if the capacitor's rated voltage you are testing happens to be between two Z Meter voltages. This prevents overloading the capacitor since you should never apply more than the capacitor's rated voltage to its terminals.

For example, a 35 volt capacitor should be tested at 25 volts, not 50 volts. Use this test voltage when looking for the allowable leakage limit on the leakage chart. (Selecting the correct leakage voltage is not a problem on the LC77 and LC102 since you can program in any voltage up to 1000 volts.)

Should I discharge the capacitor after I do the leakage test? Is it still charged?

No, the capacitor is discharged as soon as you let go of the LEAKAGE pushbutton. The Z Meter automatically places a low-value, high wattage discharging resistor across the capacitor until a front-panel pushbutton is depressed.

This feature also serves as a discharge means anytime a pre-charged capacitor is hooked up to the Z Meter. The capacitor is promptly discharged by the low-value resistor to prevent shock and to prevent any excess voltages from damaging the Z Meter's testing circuits.

Why does the Z Meter leakage voltage of the non-portable Z Meters read low when measured with a DC meter?

The non-portable Z Meters (LC53, LC75 and LC101) use a power transformer on the AC line voltage to supply their leakage voltages of 15 volts and above. This voltage is rectified but not filtered, so a regular DC meter will read the pulsating leakage voltage to be very low, typically one-third to one-half the marked value.

Simply place a capacitor (.1 uF or larger) across the Z Meter leads to accurately read the Z Meter's leakage voltage. The capacitor acts as a filter for the pulsating AC, therefore the DC meter can accurately measure the voltage.

The three, six and 10 volt ranges of these Z Meters are rectified and filtered inside of the Z Meters, so a DC meter will read these voltages correctly without an external filter. The portable Z Meters use special high frequency switching power supplies for all of their leakage voltages, which are all DC.

Why do Z Meters have two leakage ranges?

Larger value and voltage capacitors have a higher allowable leakage level than smaller capacitors. Z Meters have two separate leakage ranges to properly measure and display the leakage current of all sizes of capacitors (the LC77 and LC102 each have four ranges automatically chosen by the microprocessor).

The large leakage range measures leakage current from 0 to 9990 uA. The smaller leakage range gives greater resolution for smaller capacitors and measures from 0 to 99.9 uA. This smaller range is used for most of your capacitor leakage testing except for larger electrolytics. The leakage charts have shaded areas showing you which range to choose depending on the size of the capacitor you are testing.

Why can't I just check capacitor leakage with my ohmmeter?

Capacitor leakage is not linear with the voltage applied. Therefore, a 450 volt capacitor may show excessive leakage at 400 volts while showing almost no leakage at 50 volts.

Typically, an ohmmeter applies less than 3 volts, so it cannot test most capacitors at their working voltage. An ohmmeter can find a shorted capacitor, but many more capacitors fail because of excessive leakage.

Dielectric Absorption

- **Inability Of A Capacitor To Discharge.**
- **Two Different Tests.**
- **"WAIT" Means The Capacitor Is Still Charged.**
- **Use Dielectric Absorption Table As A Rule Of Thumb.**
- **Does Not Apply For Ceramic Capacitors.**

The Z Meters give you two different methods to measure dielectric absorption. The LC53, LC75, LC76, and the LC101 use the charge-discharge method of measuring dielectric absorption. The LC77 and the LC102 have an automatic test that displays the results directly as a percentage of dielectric absorption.

Dielectric absorption is sometimes called capacitor memory or battery action. It is simply the inability of a capacitor to discharge. The Z Meters that use the charge-discharge method of dielectric absorption detection measure the capacitor's value before and after the leakage test. The difference in the two capacitance values is the indication of the severity of dielectric absorption. The larger the difference in the two value readings, the worse the dielectric absorption is.

The residual dielectric absorption voltage of the capacitor changes the RC charge curve and makes the Z Meter see a smaller value of capacitor after the leakage test. As the test continues, the dielectric charge or memory is slowly dissipated in the charge and recharge of the capacitor. This increases the length of the RC charge curve and allows the Z Meter to read a higher and higher value capacitor until the value reading eventually agrees with the first value sample.

The LC77 and LC102 use an automatic method of measuring dielectric absorption. These Z Meters charge the capacitor to a preset level and then discharge the capacitor. The remaining voltage on the capacitor after discharge is then measured and the percentage of voltage recovery is calculated and displayed on the LCD readout. The maximum amounts of allowable dielectric absorption for the different types of capacitors are shown in figure 16.

Maximum Allowable Percent Of DA

Capacitor Type	Maximum % of DA
Double Layer Lytic	Meaningless. DA may normally be very high.
Aluminum Lytic	15%
Tantalum Lytic	15%
Ceramic	10%
All others	1%

Fig. 16: Maximum allowable amounts of dielectric absorption for the different capacitor types.

Questions & Answers

How long should I hold the leakage button in when I'm doing the dielectric absorption test? (Charge-discharge method)

You only need to hold the LEAKAGE button in until you see a "good" leakage reading on the display (usually less than 5 seconds). A "good" leakage reading for most capacitors will be near zero except for electrolytics, which have their allowable leakage limits listed in the leakage charts. You do not have to wait for a "zero" leakage reading for electrolytics. As soon as the Z Meter displays a "good" leakage reading, let the LEAKAGE button out and measure the capacitance value.

What does the term 'WAIT' mean when I push the dielectric absorption button?

The LC77 and LC102 have special circuits that delay the dielectric absorption test until the capacitor under test is fully discharged. If the Z Meter senses a voltage on the capacitor, the word "WAIT" will appear on the 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 dielectric absorption test to continue.

You may either hold the DIELECTRIC ABSORP button in and let the microprocessor discharge the capacitor, or you may let the button out and let the Z Meter's high wattage resistor automatically discharge the capacitor while you do other duties. Either way, the capacitor should be ready to test in a few seconds.

In most cases it may be faster to perform the dielectric absorption before the leakage test. Capacitors with excessive dielectric absorption will show up immediately as being bad on the dielectric absorption test. If the leakage test is performed first, the Z Meter may flash the "WAIT" sign until the capacitor recovers from the effects of the leakage voltage applied. If the capacitor has excessive dielectric absorption, the "WAIT" sign may appear for several minutes since the capacitor doesn't discharge like a normal capacitor. Any capacitor that will not test for dielectric absorption for an extended period of time is defective and should be replaced.

How do I know what is good and bad for the dielectric absorption test?

The Good/Bad limits for dielectric absorption are shown in figure 16. These limits should be used as a guide rather than a law. If a capacitor in a defective circuit shows questionable levels of dielectric absorption, you may want to replace it - especially if the capacitor is in a critical circuit.

For example, capacitors which store a DC voltage to control other circuits must have extremely low levels of dielectric absorption. 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, analog-to-digital converter, and digital- to-analog circuits need low dielectric absorption levels. Dielectric absorption values of 1% or more will often affect these critical circuits.

Capacitors used to couple AC may cause waveform distortion if dielectric absorption is too high. Audio amplifiers often develop distortion with a poor coupling capacitor. However, the dielectric absorption will generally have to be at least 5 to 15% before it causes problems in these applications. These values may show "GOOD" on the Z Meter, so be certain you judge 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 dielectric absorption before causing circuit problems. Generally, you will not see a noticeable change in performance until dielectric absorption 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.

Will ceramic capacitors show dielectric absorption?

The dielectric absorption test is not recommended on ceramic capacitors. Ceramic capacitors contain a condition called "dielectric stress" which looks a lot like dielectric absorption. An applied DC potential on a ceramic capacitor cause physical stress within the ceramic dielectric material, causing a temporary decrease in value. It takes several seconds for the capacitor to return to its non-stressed mode after removing the bias.

This dielectric stress-caused value change looks like dielectric absorption on ceramic capacitors. Due to the high sensitivity of the Z Meter measuring circuits, smaller value ceramic capacitors show the largest value of dielectric absorption on Z Meters. Figure 37 on page 38 shows the typical dielectric absorption percentages for 500 volt ceramic disc capacitors - as seen on a Z Meter after a leakage test.

The LC77 and LC102 will give you an "ERROR 3" display if you try to measure dielectric absorption on a ceramic capacitor with an entered value less than 0.01 uF. Only test ceramic capacitors for value and leakage.

ESR

- **Measures Instantaneous Voltage Rise.**
- **Can't Measure With Ohmmeter.**
- **Test Is Not Frequency Selective.**
- **Test Valid On Capacitors 1 uF And Larger.**
- **The More ESR, The Worse The Capacitor.**

A good capacitor should immediately begin charging at the RC time constant made up of the capacitance value

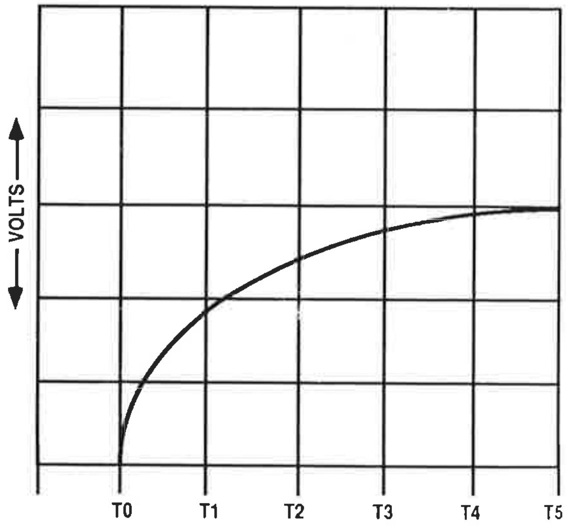


Fig. 17: When current is applied to a normal capacitor, it begins recharging from zero, building in voltage according to the normal RC charging curve.

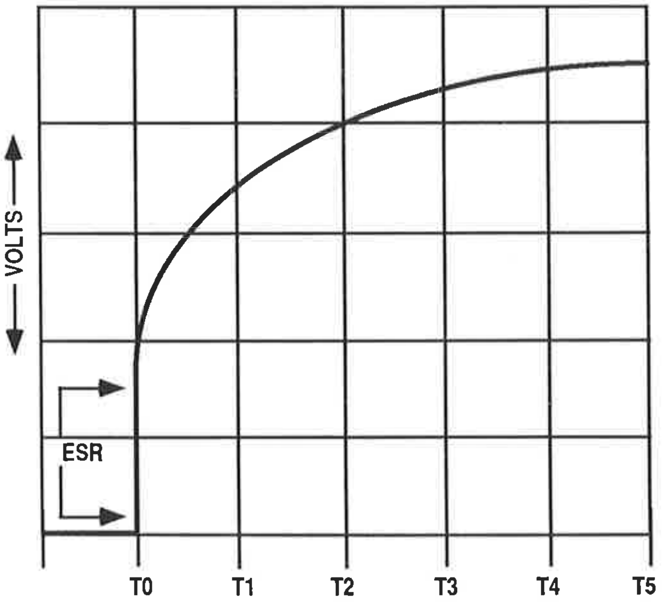


Fig. 18: When a capacitor has ESR, the charging voltage instantly rises to a proportional voltage level before beginning the normal RC charging curve.

and the output of the supply charging the capacitor. The voltage should begin at zero, and then build in the normal fashion until fully charged (5 time constants) as figure 17 shows. Charging and discharging this capacitor repeatedly results in a sawtooth waveform.

Figure 18 shows the same charging curve of a capacitor with ESR. Notice that the charging voltage instantly rises to a voltage before beginning the normal RC curve. The larger the ESR, the higher the step before the charging curve. Charging and recharging a capacitor with ESR will result in a trapezoidal waveform.

The Z Meters simply charge the capacitor while measuring the rise in voltage during the first microsecond after applying the voltage. The instantaneous voltage step calculates directly to resistance using normal voltage-dividing formulas. The maximum allowable amount of ESR is listed in figures 19 and 20. They are also included in the Z Meter's pull charts and instruction manuals.

Maximum Allowable ESR (in Ohms)

Dipped Solid Tantalum Capacitors

CAPACITY in uF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	133	133	133	79.6	79.6	79.6	79.6	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3
1.5	88.4	88.4	88.4	53.1	53.1	53.1	53.1	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2
2.2	60.3	60.3	60.3	36.2	36.2	36.2	36.2	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1
3.3	40.2	40.2	40.2	24.1	24.1	24.1	24.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
4.7	28.2	28.2	28.2	16.9	16.9	16.9	16.9	14.1	14.1	14.1	14.1	14.1	14.1	14.2	14.1	14.1
6.8	19.5	19.5	19.5	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
10	13.3	13.3	13.3	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
15	8.84	8.84	8.84	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31
22	6.03	6.03	6.03	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62	3.62
33	4.02	4.02	4.02	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
47	2.82	2.82	2.82	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
68	1.95	1.95	1.95	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
100	1.33	1.33	1.33	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
150	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
220	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
330	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
470	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
680	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1000	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1500	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2200	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3300	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
4700	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6800	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

NOTE: No industry standards are available for component values in the shaded areas. These values have been extrapolated from existing standards and manufacturers data. All values are based on existing EIA industry standards.

Fig. 19: Maximum allowable ESR for dipped solid tantalum electrolytics per EIA standards.

Maximum Allowable ESR (in Ohms)

Standard Aluminum Electrolytic Capacitors

CAPACITY in uF	1.5V	3.0V	6.0V	10V	15V	20V	25V	35V	50V	100V	200V	300V	400V	500V	600V	1000V
1.0	663	663	663	663	464	464	464	464	332	332	265	265	265	265	265	265
1.5	442	442	442	442	310	310	310	221	221	177	177	177	177	177	177	177
2.2	302	302	302	302	211	211	211	151	151	121	121	121	121	121	121	121
3.3	201	201	201	201	141	141	141	101	101	80	80	80	80	80	80	80
4.7	141	141	141	141	99	99	99	71	71	56	56	56	56	56	56	56
6.8	98	98	98	98	68	68	68	49	49	39	39	39	39	39	39	39
10	66	66	66	66	46	46	46	33	33	27	27	27	27	27	27	27
15	44	44	44	44	31	31	31	22	22	18	18	18	18	18	18	18
22	30	30	30	30	21	21	21	15	15	12	12	12	12	12	12	12
33	20	20	20	20	14	14	14	10	10	8.04	8.04	8.04	8.04	8.04	8.04	8.04
47	14	14	14	14	9.88	9.88	9.88	7.06	7.06	5.65	5.65	5.65	5.65	5.65	5.65	5.65
68	9.76	9.76	9.76	9.76	6.83	6.83	6.83	4.88	4.88	3.90	3.90	3.90	3.90	3.90	3.90	3.90
100	6.63	6.63	6.63	6.63	4.64	4.64	4.64	3.32	3.32	2.65	2.65	2.65	2.65	2.65	2.65	2.65
150	4.42	4.42	4.42	4.42	3.10	3.10	3.10	2.21	2.21	1.77	1.77	1.77	1.77	1.77	1.77	1.77
220	3.02	3.02	3.02	3.02	2.11	2.11	2.11	1.51	1.51	1.21	1.21	1.21	1.21	1.21	1.21	1.21
330	2.01	2.01	2.01	2.01	1.41	1.41	1.41	1.01	1.01	.804	.804	.804	.804	.804	.804	.804
470	1.41	1.41	1.41	1.41	.988	.988	.988	.706	.706	.565	.565	.565	.565	.565	.565	.565
680	.976	.976	.976	.976	.683	.683	.683	.488	.488	.390	.390	.390	.390	.390	.390	.390
1000	.663	.663	.663	.663	.464	.464	.464	.332	.332	.265	.265	.265	.265	.265	.265	.265
1500	.442	.442	.442	.442	.310	.310	.310	.221	.221	.177	.177	.177	.177	.177	.177	.177
2200	.302	.302	.302	.302	.211	.211	.211	.151	.151	.121	.121	.121	.121	.121	.121	.121
3300	.201	.201	.201	.201	.141	.141	.141	.101	.101	.080	.080	.080	.080	.080	.080	.080
4700	.141	.141	.141	.141	.099	.099	.099	.071	.071	.056	.056	.056	.056	.056	.056	.056
6800	.098	.098	.098	.098	.068	.068	.068	.049	.049	.039	.039	.039	.039	.039	.039	.039
10000	.066	.066	.066	.066	.046	.046	.046	.033	.033	.027	.027	.027	.027	.027	.027	.027
15000	.044	.044	.044	.044	.031	.031	.031	.022	.022	.018	.018	.018	.018	.018	.018	.018
22000	.030	.030	.030	.030	.021	.021	.021	.015	.015	.012	.012	.012	.012	.012	.012	.012
33000	.020	.020	.020	.020	.014	.014	.014	.010	.010							
47000	.014	.014	.014	.014	.010	.010	.010									
56000	.012	.012	.012	.012												
68000	.010	.010	.010	.010												

NOTE: No industry standards are available for component values in the shaded area. These values have been extrapolated from existing standards and manufacturers data. All values not shaded are based on existing EIA industry standards.

Fig. 20: Maximum allowable ESR for aluminum electrolytics per EIA standards.

Questions & Answers

Can I measure ESR with an ohmmeter?

No. ESR is the resistances in series with a capacitor. An ohmmeter cannot measure ESR because it is impossible to connect an ohmmeter across the resistances inside the capacitor.

The circuits that measure ESR must be able to ignore other capacitor parameters, including capacitance reactance at a given frequency. An ohmmeter can't do that because the capacitor blocks any attempt to measure with DC.

Are the Z Meter ESR tests frequency selective?

Since ESR is purely resistive, it does not have to be tested at a frequency. Attempts have been made to convert D (dissipation factor) to an ESR reading. Since ESR is only one of many imperfections that cause poor D readings, and D is frequency selective, it would seem that ESR is frequency selective. But this is not the case since resistance has the same impedance at any frequency.

A capacitor with ESR may react differently at different frequencies, however. For example, a 60 Hz power supply capacitor charges and discharges at a fairly slow rate. Thus the heating effect due to ESR can be fairly low. As the frequency increases, however, the rate at which the current flows into and out of the capacitor increases, more heat is generated, therefore more power is lost at these frequencies.

In the case of the aluminum electrolytic capacitor, this additional heat has the effect of accelerating the chemical processes going on in the capacitor and, thus, the life of the capacitor is decreased.

Why is ESR a factor only on capacitors of 1 uF and larger?

Capacitor ESR only causes problems in circuits that use capacitors larger than 1 uF. There may be ESR on lower value capacitors, especially ceramic capacitors, but it won't affect the circuits. High levels of ESR may even cause the capacitor's value to read low.

All Z Meters but the LC53, LC77 and LC102 will test for ESR on capacitors smaller than 1 uF, but the test is meaningless. The LC77 and LC102 are programmed to display an ERROR message whenever they're testing ESR on capacitors under 1 uF.

Testing And Identifying Different Capacitor Types

Many different types of capacitors are used in electronics. Each type has certain properties that make it better suited for particular applications. Properties such as temperature coefficient, ESR, dielectric absorption, leakage, voltage breakdown, and frequency characteristics are taken into account when selecting the capacitor type to be used. When troubleshooting a circuit, it is not important to know why a certain type of capacitor was selected. It is best to simply replace a bad capacitor with a good capacitor of the same type value and voltage rating. This is especially true when the component is in a "Safety Critical" circuit. Because different capacitor types have different characteristics, it is important that you know what type of capacitor you are testing in order to know if the Z Meter test results are acceptable or not.

Fig. 21: Capacitors come in many shapes and sizes, all with different testing characteristics.

There are many different types of capacitors, using different types of dielectrics, each with its own best capability. When replacing capacitors, it is best to replace with a capacitor having not only the same capacity and tolerance, but the same type of dielectric and temperature characteristics as well. This will ensure continued performance equal to the original.

The capacitor is often named according to the type of dielectric which is used, such as paper, mylar, ceramic, mica, or aluminum electrolytic. Paper and mica were the standard dielectric materials used in capacitors for years. Ceramic became popular due to its stability and controlled characteristics and lower cost over mica. Today, there are many dielectrics with different ratings and uses in capacitors.

This section is intended to help you identify the different types of capacitors and recognize the different Z Meter testing characteristics of each.

Aluminum Electrolytics

	Value	Leakage	DA	ESR
Aluminum Lytic	X	X	X	X

- **Large Capacity In Small Package.**
- **Two Aluminum Plates Separated By Moist Paper.**
- **Date Code Printed On Case.**
- **Leakage And Dielectric Absorption Are Most Common Failures**
- **Normally Show Some Leakage.**
- **Leakage Reading Does Not Have To Be Zero.**
- **They Will Fail On Shelf Or If Left Unused.**
- **Value Normally Reads High.**

Aluminum electrolytic capacitors are one of the most common capacitors used today. These capacitors have become common because they offer a large capacitance in a small place. This makes them ideal to use as filters in power supplies and couplers in low frequency circuits. However, aluminum electrolytic capacitors are also the least reliable capacitors on the market, because eventually every one of them will fail.

An aluminum electrolytic capacitor consists of two aluminum foil plates separated by a porous strip of paper soaked with a conductive solution called the "electrolyte". This moist paper, however, is not the capacitor's dielectric. It serves as a spacer to prevent the two plates from mechanically shorting. The electrolyte conducts the charge from the negative plate, through the paper, and into direct contact with the dielectric. The dielectric is a thin layer of aluminum oxide that is electrochemically formed on the positive foil plate. The key to an electrolytic is the fact that the capacitance increases linearly as the thickness of the dielectric decreases. Therefore, because of their extremely thin dielectric, electrolytics can have a large capacitance within a small volume. Figure 23 shows the construction of an aluminum electrolytic.

After this capacitor sandwich is made, it is rolled up and placed in a cylindrical case. The case is then stamped with a manufacturing label. Most capacitors have the manufacturing date printed on the case along with the label. This date is printed in the form of a four digit number. The first two digits represent the year that the capacitor was produced, and the last two numbers signify the week of the year it was produced.

For example, a capacitor made in the 26th week of 1982 would have a date code of 8226 stamped on its case. By checking this date you can determine exactly how long a capacitor has been sitting on a shelf.

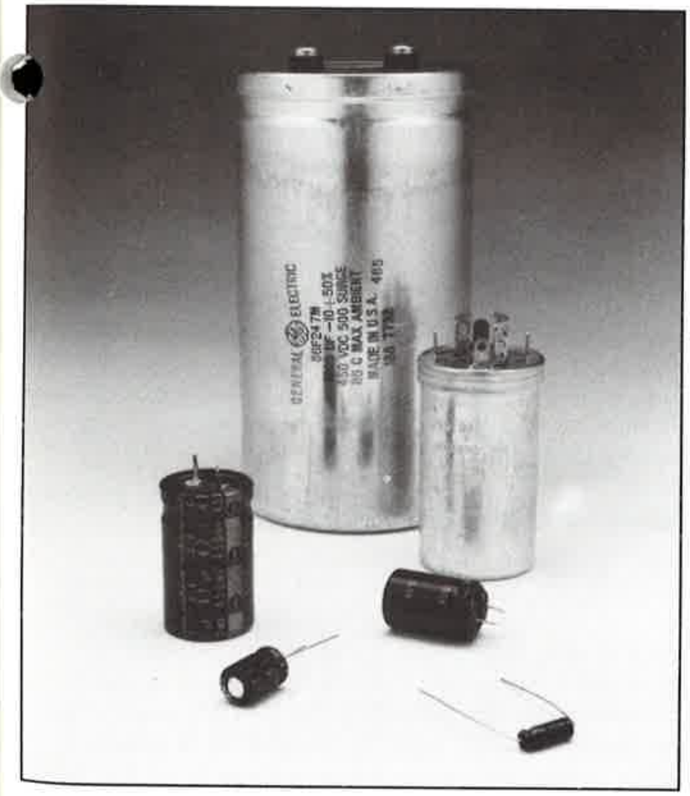


Fig. 22: Aluminum electrolytics contain a large capacity in a small package.

Since the electrolyte inside the capacitor is water based, the electrolyte will eventually dry out, causing capacitor malfunction. As long as the electrolyte remains liquid, the capacitor is good or can be reformed after sitting for a while. When the electrolyte drys out, the leakage goes up and the capacitor loses capacity. This can happen to aluminum electrolytics just sitting on the shelf. When an aluminum lytic starts drying out, the capacitor begins to show dielectric absorption. Excessive ESR is also a common failure condition for aluminum electrolytic capacitors.

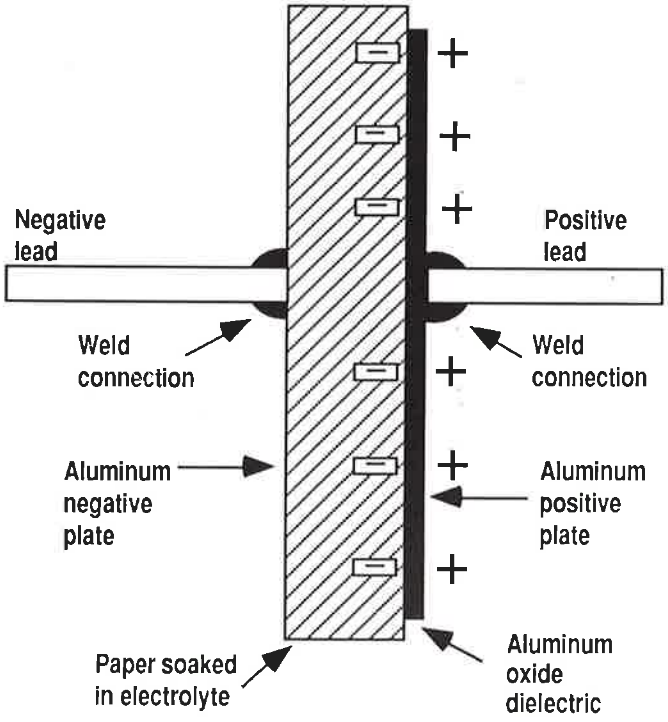


Fig. 23: Basic construction of an aluminum electrolytic capacitor.

Value Change

Capacitors can change value while in a circuit or while sitting on the shelf, especially aluminum electrolytics. As these capacitors dry out, they eventually lose their capacitance due to the failure of the aluminum oxide film making up the dielectric. A change in value in an aluminum electrolytic will often also be preceded by other defects, such as high leakage, high dielectric absorption and/or high ESR.

Aluminum electrolytics generally have a marked value tolerance, for example, +80% - 20%. If the capacitor's value is not within the marked tolerance, the capacitor could cause problems such as large ripple currents in a power supply or a loss of low frequency response in electrolytically coupled circuits.

One of the causes for an aluminum electrolytic capacitor to change value is the electrolyte's drying out. After the electrolyte dries out, the charge on the negative foil

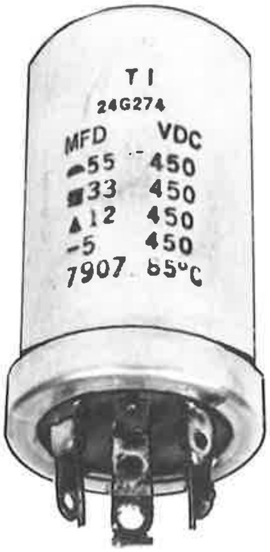


Fig. 24: The date code, found on many larger aluminum electrolytics, is a four-digit number indicating the year and the week the capacitor was made. The circled 7907 indicates the capacitor was manufactured in the 07th week of '79.

plate has no way of coming in contact with the aluminum oxide dielectric. The dried out paper spacer then becomes a second dielectric, which decreases the capacitance drastically.

Leakage

One of the most common aluminum electrolytic capacitor failures is caused by current leaking through the capacitor. Some electrolytics will show a gradual increase in leakage, while others will change rapidly and even short out entirely. Capacitors are supposed to block DC signals while passing AC signals. A leaky capacitor passes DC current along with the AC signals. This upsets the DC biasing in the circuit and loads down power supplies.

In order to effectively test a capacitor for leakage, it is necessary to test the capacitor at its rated voltage. An ohmmeter can be used to locate a completely shorted capacitor, but many capacitors show no leakage at the low voltages present in an ohmmeter. The Z Meters are the only capacitor testers available that dynamically test capacitors for leakage and they do it at the rated voltage of the capacitor.

All aluminum electrolytics have some leakage, and a certain amount of leakage is allowable in these capacitors. The maximum allowable leakage of these capacitors is a specification published by the manufacturer. Z Meters provide these limits in an easy to read reference table (figure 14, page 22) included in the Z Meters' pull charts and operation manuals.

As long as the Z Meter reads less leakage than the value listed in the reference table, the capacitor is good. An aluminum electrolytic will take a short amount of time to charge, so you may not read an acceptable level of leakage current for two or three updates of the Z Meter display. YOU DO NOT NEED TO WAIT FOR A ZERO LEAKAGE READING.

Specifically: *As long the leakage reading reaches a level that is below the maximum leakage level, you can stop the leakage test because you have proved the capacitor good.*

The charging time for aluminum electrolytics varies with capacity and applied voltage. On larger electrolytics, the Z Meter will overrange until the charging current drops below a 10 mA (20 mA on the LC77 and LC102). The typical amount of overrange time can be determined from figure 12 on page 20. After the Z Meter stops overranging, the display usually begins at a high leakage reading and drops with each display update. This shows the charging action of the capacitor through the impedance of the leakage power supply circuits. When an aluminum electrolytic is fully charged, the reading will change in small steps, either up or down. These small changes simply indicate that the capacitor under test is attempting to filter small changes in the charging voltage. It is not necessary, in most cases, to wait until the capacitor is fully charged to determine if it is good. Just depress the LEAKAGE pushbutton until the leakage drops below the maximum allowable level shown in the reference tables.

Aluminum electrolytics do not need to be in a circuit to develop leakage; they can develop it just by sitting on the shelf. As the capacitor ages on the shelf, its aluminum oxide dielectric slowly dissolves into the electrolyte, and the dielectric becomes thinner. When a high voltage is placed across this capacitor, the weakened dielectric begins to conduct a DC current, and the capacitor begins to electrically look like a capacitor with a resistor across it. For this reason, it's always a good idea to test new aluminum capacitors before installing them into circuit.

Reforming Aluminum Electrolytics

Aluminum electrolytic capacitors often decrease in value and develop leakage if they sit unused for long periods of time. Electrolytics that sit on the stockroom shelf unused commonly exhibit this type of problem. These symptoms are caused by the loss of some of the oxide dielectric. The oxide is formed by a chemical reaction in the electrolyte when voltage is applied to the plates. With time, this oxide deteriorates. In many cases the electrolyte has not dried up and the oxide coating can be reformed by applying a DC voltage to the capacitor for a period of time.

The Z Meters' leakage power supply test voltage can be used to reform electrolytics. You can use the supplied 39G145 or 39G201 Test Button Hold Down Rod and the

Z Meter to apply the rated leakage voltage to the capacitor for extended periods of time. Once the leakage current of the capacitor has dropped below the maximum limit, you may use the capacitor in circuit. If the reforming process does not reduce the leakage current to an acceptable level, the electrolytic is defective and should be discarded.

Dielectric Absorption

Dielectric absorption is a common failure of aluminum electrolytic capacitors. It is basically the inability of the capacitor to fully discharge when its terminals are short circuited.

As a voltage is applied to an electrolytic capacitor, the dipoles in the capacitor's dielectric become polarized and line up in an organized fashion. After removing the applied voltage and short circuiting the capacitor, the dipoles should return to a random, unorganized state. In a capacitor with dielectric absorption, however, some of the dipoles remain in their polarized position after discharging the capacitor. These dipoles then cause a charge to reappear on the capacitor's plates. This charge, called dielectric absorption, will cause poor filtering and distorted waveforms.

The earliest indicator of an aluminum electrolytic capacitor drying out is an increase of dielectric absorption. However, electrolytics are manufactured with a small amount of dielectric absorption. This nominal amount of dielectric absorption will remain small while the capacitor remains functional. Before the capacitor becomes defective though, its dielectric absorption generally increases. This increase, however, is not linear over time. The capacitor's dielectric absorption will increase slowly at first, and as the capacitor's life nears its end, its dielectric absorption will rise drastically. This makes dielectric absorption an excellent life indicator because a capacitor with a considerable amount of dielectric absorption will only have a short life remaining.

ESR

Problems associated with excessive ESR have increased in the last few years due to the ever increasing use of aluminum electrolytic capacitors and the use of these capacitors in higher frequency circuits. ESR is also a problem in low frequency circuits, but it is more noticeable in the high frequency circuits.

In the past, most power supplies operated at the AC power line frequency. In these power supplies, the current flow into and out of the capacitor occurred at a rate of 60 to 120 cycles per second. At these frequencies, capacitors would tolerate a fair amount of ESR without generating an excessive amount of heat.

Today, however, we are seeing the rapid increase in the use of switching power supplies which operate at significantly higher frequencies. These power supplies may be scan derived power supplies running off of the horizontal flyback pulses in a television set, or they may be chopping power supplies running at frequencies substantially higher than 60 cycles per second. Switching power supplies are becoming more popular because they eliminate the low voltage ripple associated with the traditional line operated power supplies, plus they can eliminate the need for heavy and costly power transformers. Capacitors used in switching power supplies have currents flowing in and out at very high rates, and any increase in the capacitor's ESR will result in a rapid increase in temperature.

An electrolytic capacitor which has excessive ESR will develop internal heat which greatly reduces the life of the capacitor. In addition, ESR changes the impedance of the capacitor in circuit since it has the same effect as adding an external resistor in series with the component.

The maximum amount of ESR allowable for aluminum electrolytic capacitors is listed in figure 20 on page 27 which is also in the Z Meter pull charts and manuals. The capacitor under test is good if the measured ESR is below the limit listed in the reference chart. If the ESR exceeds the amount listed in the chart, the capacitor is bad and should be replaced.

Questions & Answers

How do I test multi-section aluminum electrolytics?

Multiple section aluminum electrolytic capacitors are common, especially in many older power supplies. Such capacitors are actually several capacitors, inside one can, sharing the same negative terminal.

These capacitors should be tested for all four failure modes, individually. Each section is acting on its own and serves its own function in the circuit, so each section must be thoroughly tested. The only thing shared by the individual sections is the ground, which many times will be connected to the case of the capacitor.

Leakage sometimes develops between one or two sections of multi-section electrolytics. This leakage is especially difficult to troubleshoot without the Z Meter leakage test because signals from one section of the capacitor are coupled to another section. This results in multiple symptoms in the operation of the device in which the capacitor is used. An ohmmeter will not show leakage between sections of a multi-layer capacitor because the leakage only occurs near the capacitor's operation voltage.

To isolate this type of leakage with the Z Meter you simply perform the standard leakage test. As you test each section, short each of the remaining sections to ground. Any increase in leakage when a section is shorted to ground indicates leakage between sections.

What does flashing 8's mean when I'm performing the leakage test on an aluminum electrolytic?

One of three things: 1. The capacitor is still charging; 2. The capacitor has excessive leakage or is shorted; or, 3. The Z Meter's voltage setting or leakage range switch is set wrong.

1. Larger aluminum electrolytics may take a few seconds to charge before the Z Meter will show a leakage reading. For the first few seconds of charging, the capacitor may take more charging current than the Z Meter can display, hence the overrange condition. The typical overrange times are listed in figure 12.

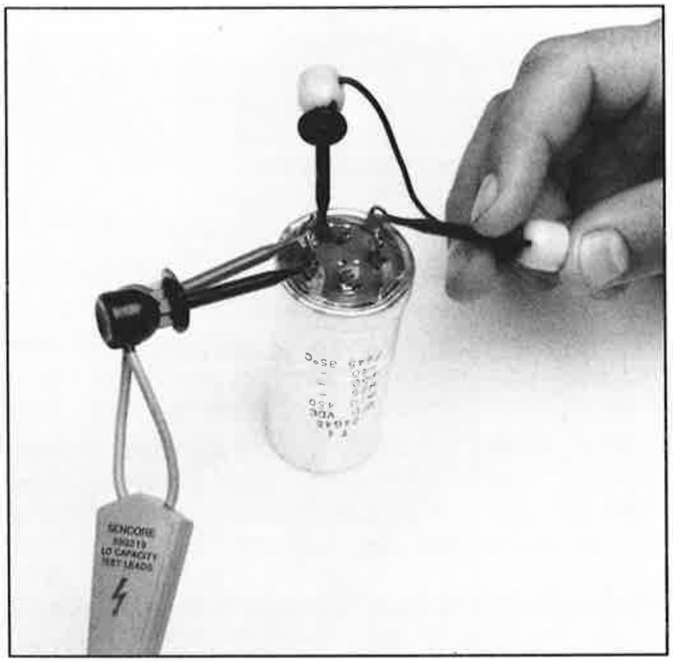


Fig. 25: Test the leakage of one section of a multisection lytic, then short one of the remaining sections to ground. Any increase in leakage current indicates leakage between that section and ground.

2. An extremely leaky aluminum electrolytic capacitor may flash 8's for the leakage reading. This just indicates that the leakage is very high which will cause circuit problems. If attempts at reforming the capacitor fail, the capacitor is bad and cannot be repaired.

If you are performing the leakage on any shorted cap, the display will flash 8's all the time. Since the Z Meter leads are across a short circuit when it is hooked up to a shorted capacitor, the leakage test will draw maximum current and the display will overrange.

3. Make sure the voltage setting of the Z Meter matches the rated voltage of the capacitor under test. If the capacitor is tested with a voltage higher than its rated voltage, the leakage reading will be high (it may flash 8's) and the capacitor could be damaged.

If the aluminum electrolytic capacitor under test is a fairly large one, make sure the LEAKAGE RANGE switch is in the larger range. Check the leakage reference charts for which range the capacitor falls into. If the smaller range is chosen for a larger capacitor, an overrange condition may result on the Z Meter's display. (The LC77 and LC102 automatically choose the range for you.)

Why do Z Meters always read a high value on aluminum electrolytics?

When aluminum electrolytic capacitors are manufactured, their values are measured and stamped on their cases. Most of the time, however, their values are measured with an AC bridge. As discussed earlier, a Z Meter will normally read electrolytics' values much higher due to the frequency selective effects.

Normally, a higher value of electrolytic will not adversely affect its circuit. It's the low value aluminum electrolytic that will cause the problems. But, an electrolytic that reads extremely high on the Z Meter (100% high or more) often has other problems that will show up on one of the other three capacitor tests.

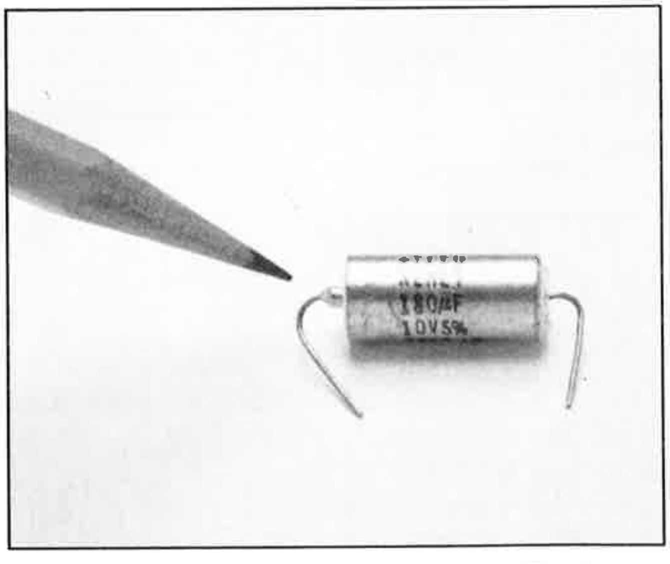


Fig. 26: Axial lead tantalum capacitors, like the one shown here, are easily identified from axial lead aluminum electrolytics by a solder weld on one end.

Identifying Aluminum Electrolytics

Aluminum electrolytic capacitors are the easiest capacitor types to identify. They are most commonly cylinder shaped and have radial or axial leads. Large value aluminum lytics often have screw terminals or solder lugs. The case of an aluminum electrolytic usually is rolled in or formed out near the lead end to hold the end cap and seal. All aluminum electrolytics have a seal that is soft and rubber-like to allow gasses to vent. Depending on the physical size of the case, the soft seal may make up the entire end of the case, or it may be just a small section of a hard end cap.

Aluminum electrolytics have a large physical size to capacity ratio. These capacitors may also have several sections, with each section having a different capacitance value but sharing the same negative terminal, usually the case.

Because of their unique physical characteristics, most aluminum electrolytics aren't easily confused with other capacitor types. Axial lead aluminum electrolytics, however, may possibly be mistaken for axial lead tantalum electrolytics. The lead weld, shown in figure 26, is an identifying characteristic of the tantalum in electrolytic and is a quick way to differentiate between an axial lead aluminum electrolytic and a tantalum electrolytic. Aluminum electrolytics do not have a lead weld on either terminal.

Tantalum Electrolytics

	Value	Leakage	DA	ESR
Tantalum	X	X	X	X

- **Lower leakage and ESR than aluminum electrolytics.**
- **Large capacity in a small package.**
- **Polarized leads.**

The tantalum electrolytic capacitor is becoming very popular. While the leakage in the aluminum electrolytic is very high due to the nature of its construction, leakage in tantalum capacitors is very low. In addition, tantalum capacitors can be constructed with much tighter tolerances than the aluminum electrolytic. The tantalum is much smaller in size for the same capacity and working voltage than an aluminum electrolytic. Tantalum electrolytics are popular in circuits where high capacity and low leakage is required. The capacity and voltage rating of the tantalum electrolytic is limited, so for extremely large values of capacity and higher voltages in power supply filtering, the aluminum electrolytic is still the first choice.

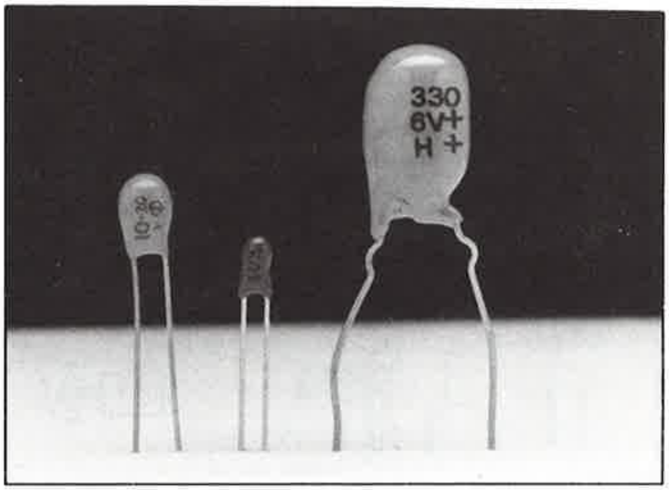


Fig. 27: Tantalum electrolytic capacitors provide a large capacity in a small package with much tighter tolerances than aluminum electrolytics.

Since the tantalum is much different in construction than an aluminum electrolytic, different reference charts are used for leakage and ESR measurements. These reference charts are shown in figures 13 and 19, plus they are included in the Z Meters' pull charts and manuals.

Identifying Tantalum Electrolytics

Tantalum electrolytics are rapidly replacing aluminum electrolytics in many electronic circuits. Besides having less leakage and higher value tolerances than aluminum electrolytics, tantalums are about one half the size of a similar aluminum electrolytic of the same value and voltage rating.

The most common shapes of tantalum capacitors are illustrated in figures 27 and 28. While they may have many shapes, tantalum capacitors always have polarized leads. Lead polarization is often the only way to distinguish a tantalum electrolytic from another type of capacitor. Once you become familiar with the polarity markings used, tantalum electrolytics are not difficult to identify. The polarity markings are not meant to be difficult to notice or understand, although if you are not aware of them, they might be overlooked. Pay careful attention so that you do not overlook the polarity indication and misidentify a tantalum capacitor as another type.

The simplest and most common polarity indicator is a "+" sign near one of the leads. This is often used along

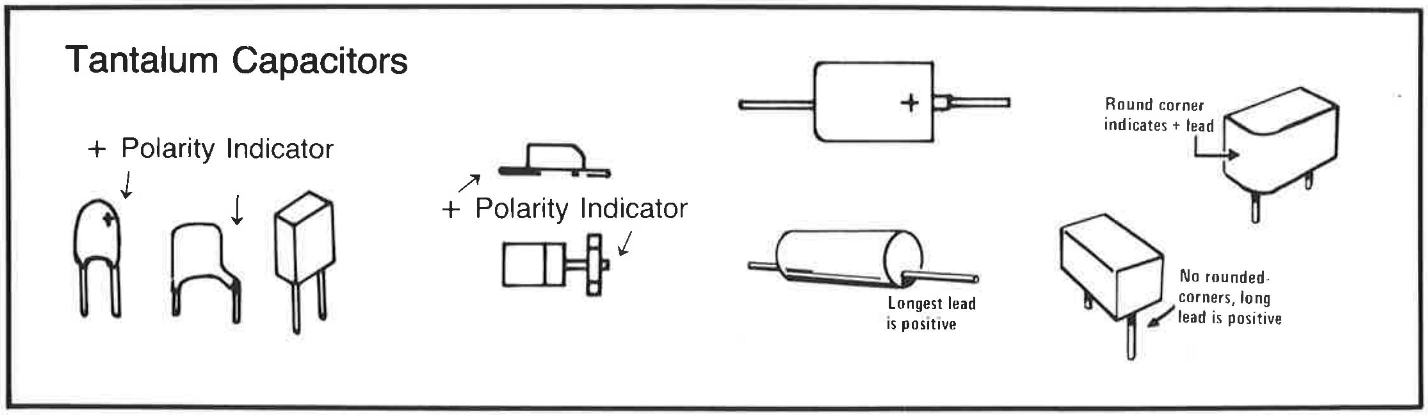


Fig. 28: Each type and shape of tantalum electrolytic capacitor has a polarity indicator.

with a second type of indicator. Figure 28 shows several examples of lead identification used in tantalum capacitors. In addition to the "+" sign, each capacitor shown has a second indication of the "+" lead: a lead weld, a tapered case, a rounded corner, a line, or an extra ridge near the "+" lead.

A "+" indicator is not printed on all tantalum capacitors. In many cases the polarity indicator will simply be the lead weld, a tapered case or rounded corner, a line or an extra ridge on the case. Several other polarity identifiers are also used. The end or side nearest the plus lead may be painted one color. Also at times, just a dot or a line on the side of the package will be used.

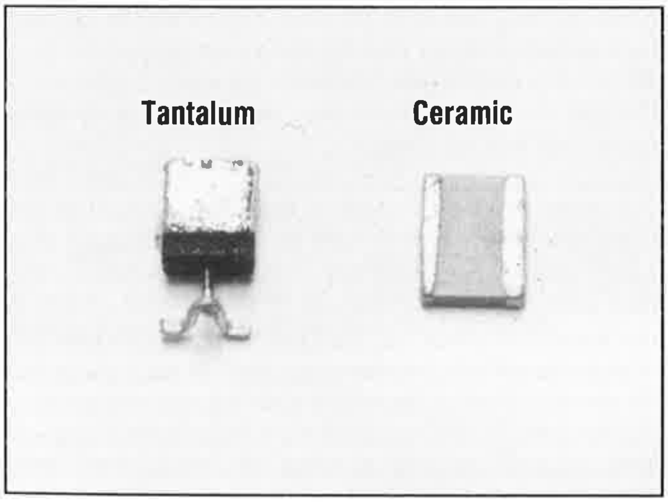


Fig. 29: A tantalum chip capacitor (left) can be identified from a ceramic chip capacitor by its positive lead.

Tantalum capacitors are also available in the small surface mount or "chip" type. Tantalum chip caps could be confused with the ceramic chip cap, since they are similar in size and appearance at first glance. But as figure 29 shows, a tantalum chip capacitor is polarized and has an easily identifiable positive lead.

The polarity identification that may give you the most difficulty in identifying a tantalum capacitor is lead length. The only identification of the positive lead on some tantalum capacitors is that it is longer than the other lead. Of course, this presents no problem when the capacitor is new, but once it has been installed into a circuit board, the leads are cut off to the same length. In this situation, use the circuit as the clue to the capacitor's type and polarity.

Double Layer Electrolytics

	Value	Leakage	DA	ESR
Double Layer Lytic	X			

- **Very large capacity for their size - marked in Farads.**
- **Extremely slow charge and discharge times.**
- **Use the capacitor value test for these capacitors.**
- **Works on LC77 and LC102.**

Double layer electrolytic capacitors are commonly known by trade names such as "Supercap" or "Gold

Dipped Tantalum Capacitors

Color	Rated Voltage	Capacitance in Picofarads		Multiplier
		1st Figure	2nd Figure	
Black	4	0	0	—
Brown	6	1	1	—
Red	10	2	2	—
Orange	15	3	3	—
Yellow	20	4	4	10,000
Green	25	5	5	100,000
Blue	35	6	6	1,000,000
Violet	50	7	7	10,000,000
Gray	—	8	8	—
White	3	9	9	—

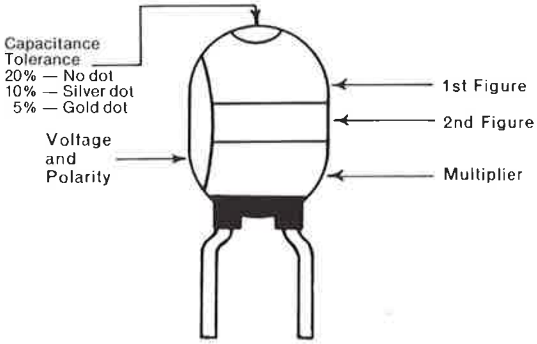


Fig. 30: Use these charts to identify values of dipped tantalum capacitors.

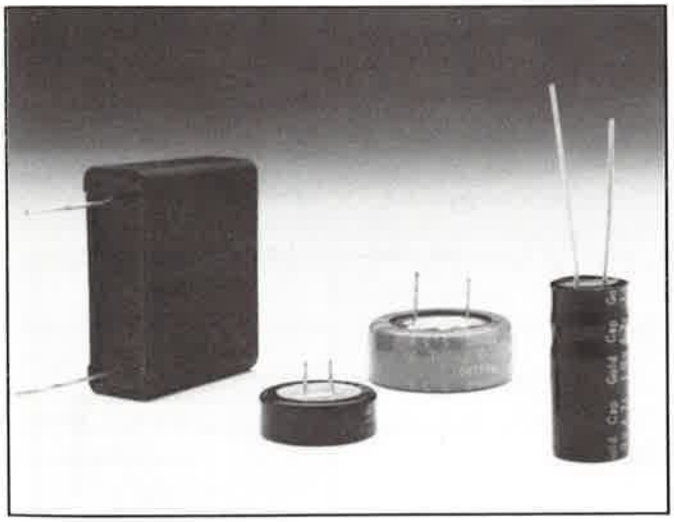


Fig. 31 Double layer electrolytic capacitors have a very large amount of capacitance for their physical size. Their value is usually marked in Farads.

Cap". These capacitors have an extremely large capacitance value for their physical size. Double layer electrolytics are usually marked in Farads, rather than microfarads or picofarads. The LC77 and LC102 will show you a capacitor value reading directly in Farads on the display. Other Z Meters will not test these capacitors because their value exceeds the measuring limits of these Z Meters.

Since double layer electrolytics have such a large capacity, it may take a few seconds for the Z Meter to display the test results. The larger the capacity the longer it takes for the Z Meter to display the results.

The leakage and dielectric absorption tests are less practical on double layer electrolytics. With such a large capacitor, the charge time may be several minutes or longer before the leakage test shows any readable numbers. And since the discharge time is equally as long, the capacitor may have to be discharged for several hours to perform the dielectric absorption test.

The best Z Meter test for double layer electrolytics is the value test. The capacitance reading should be within tolerance of the capacitor, or it is bad. You should use the first value reading that the LC77 displays. The subsequent readings may vary widely since these capacitors normally contain such a high level of dielectric absorption. The LC102 may take a little longer to display a reading, but the first reading is locked on the display so the subsequent, inaccurate readings don't confuse you.

The polarity of a double layer electrolytic is often printed on the case, although a longer lead may also be used to identify the positive terminal. Some double layer lytics use a line next to one lead which may be either "+" or "-". If there is no other marking, the terminal that is part of the metal case is the negative lead.

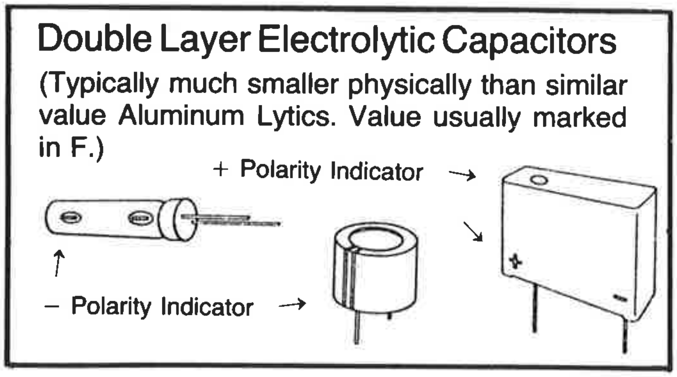


Fig. 32: The positive lead of a double layer electrolytic is usually identified by a "+" marking.

Non-Polarized Electrolytics

	Value	Leakage	DA	ESR
Non - Polarized Lytics	x	x		

- **Two polarized capacitors back-to-back.**
- **Check leakage in both directions**
- **Dielectric absorption and ESR tests are not necessary.**

A non-polarized electrolytic acts like two polarized electrolytics back-to-back. Figure 34 shows a schematic representation of a non-polarized electrolytic. The important thing here is that in effect the negative leads of two normal electrolytics are connected internally.

The value of a non-polarized electrolytic can be tested in either direction. The leakage, however, must be tested in both directions since the capacitor is effectively two electrolytics connected in series in different polarities. Dielectric absorption and ESR are not factors in this type of capacitor.

Non-polarized electrolytics are typically used in circuits having no DC voltage or established polarity. Two common circuits that use the non-polarized electrolytic capacitor are audio crossovers and AC motor start circuits. These circuits use non-polarized electrolytics for inducing phase shifts or selective filtering.

If both ends of the non-polarized electrolytic are insulated from the case, the maximum allowable leakage is the same as listed in the leakage chart for standard electrolytics of the same value and voltage. If one end is connected to the case, the allowable leakage is twice the maximum for a standard capacitor of the same value and voltage. Refer to figure 35 for examples.

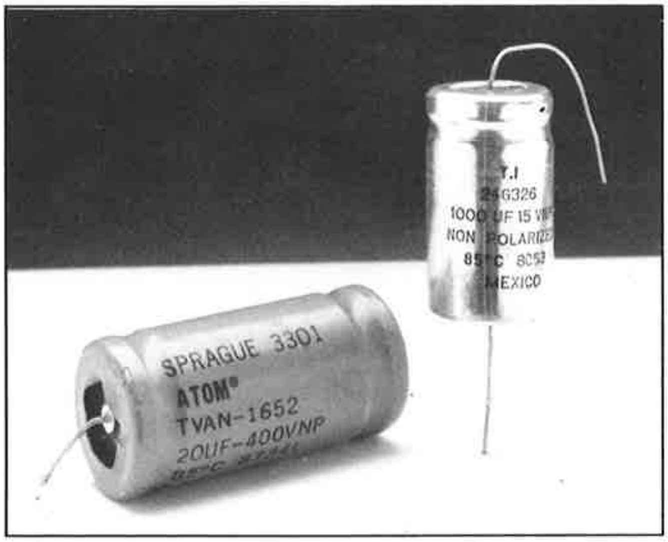


Fig. 33: Non-polarized electrolytics look like standard electrolytics but have no polarity markings.

The non-polarized electrolytic capacitor can usually be identified by its shape and the lack of polarity markings. If you aren't sure, refer to the schematic of the circuit the capacitor is used in. The non-polarized capacitor is similar in appearance to a polarized electrolytic, but there are no polarity markings.

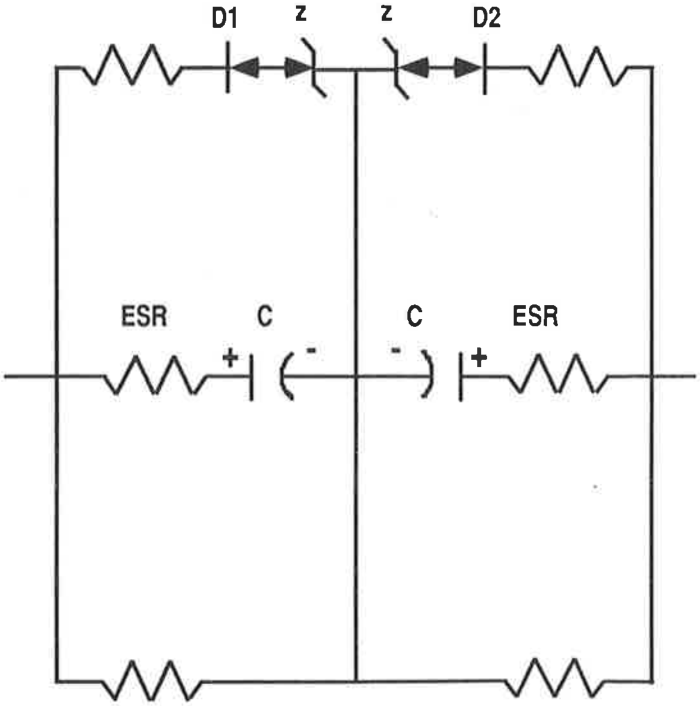


Fig. 34: A schematic representation of a non-polarized electrolytic capacitor.

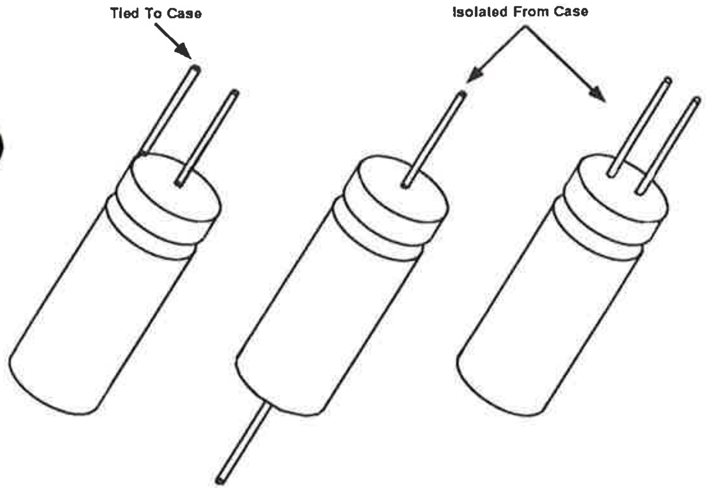


Fig. 35: A non-polarized electrolytic capacitor can either be isolated from the case, or it can have one of the leads tied directly to the case.

Ceramic Capacitors

	Value	Leakage	DA	ESR
Ceramic	X	X		

- **Most versatile capacitor.**
- **Check for value and leakage.**
- **Very small amounts of leakage are normal: less than 10 uA is common.**
- **Monolithics are smaller, but may read a higher value.**
- **NPO and COG types don't change value with temperature.**
- **N type's value decreases as temperature increases.**
- **P type's value increases as temperature increases.**

Ceramic capacitors are the most versatile capacitor of all. Many variations of capacity can be created by altering the ceramic material. Ceramic capacitors will change value with a change in temperature, applied voltage, and frequency of the signal that is applied to it. Circuit designers take advantages of these characteristics to take advantage of other circuit variables.

The most common failures of the ceramic capacitor are leakage or a shorted capacitor. The value and leakage tests of the Z Meter will find these bad ceramic capacitors. A ceramic capacitor with leakage will normally exhibit hundreds of microamps of leakage current or more. Some ceramic capacitors may exhibit some normal leakage current, usually several microamps or less. This small leakage is not a problem since it is simply showing the leakage of insulators, coatings, etc.

Most ceramic capacitors have a typical 500 volt rating. If the capacitor is not marked for voltage, test the leakage at 500 volts with your Z Meter. If the voltage is marked, test the capacitor at its rated voltage

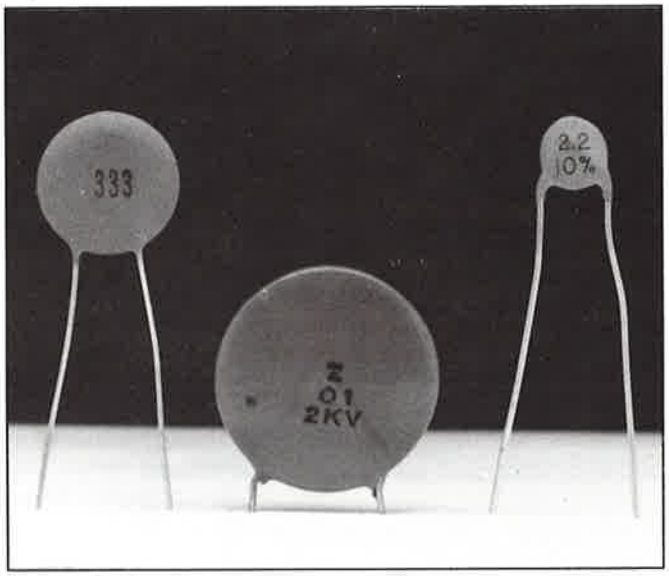


Fig. 36: Ceramic capacitors are the most versatile capacitors, but have special parameters which require different testing procedures.

Dielectric Stress

The value of most ceramic capacitors normally changes when they are DC biased. This value change is caused by "dielectric stress". The applied DC potential causes physical stress within the ceramic dielectric material, causing a decrease in value. It takes several seconds for the capacitor to return to its non-stressed mode after removing the bias.

Dielectric stress causes the capacitor to read a lower value on the Z Meters immediately after performing a leakage test compared to the value read before the leakage test. After the leakage test, the value reads low and slowly builds back up to the first value reading as the dielectric stress dissipates. This effect looks like dielectric absorption in other types of capacitors.

Small value ceramic capacitors show a larger percentage value change than larger ones due to the high sensitivity of the Z Meter's value test circuits. The circuits are so sensitive that they detect even small amounts of dielectric stress and absorption in the Z

Meter's own internal switches, printed circuit boards, and test leads. These changes amount to about 2 pF when the Z Meter's front-end circuits have been charged to the typical 500 volt rating of most ceramic capacitors. Thus, a 2 pF capacitor may show more than a fifty percent change in value after testing leakage as the dielectric stress factors of the front-end and the capacitor combined.

The following figure shows typical value changes for 500 volt ceramic disc capacitors, as seen on a Z Meter after performing the leakage test:

Value	Percentage Change
Under 10 pF	50%
10-15 pF	35 %
15-40 pF	20 %
40 pF & up	15 %

Fig. 37: Ceramic capacitors normally show a high level of dielectric absorption due to a condition called "dielectric stress". The dielectric absorption test is not recommended on ceramic capacitors.

Monolithic Ceramic Capacitors

Monolithic ceramic capacitors combine a relatively large value with a small size. Figure 38 shows two .47 uF capacitors, a 10 volt conventional disc on the left and a 50 volt monolithic capacitor on the right. Notice how much smaller the 50 volt monolithic type is compared to the 12 volt conventional disc.

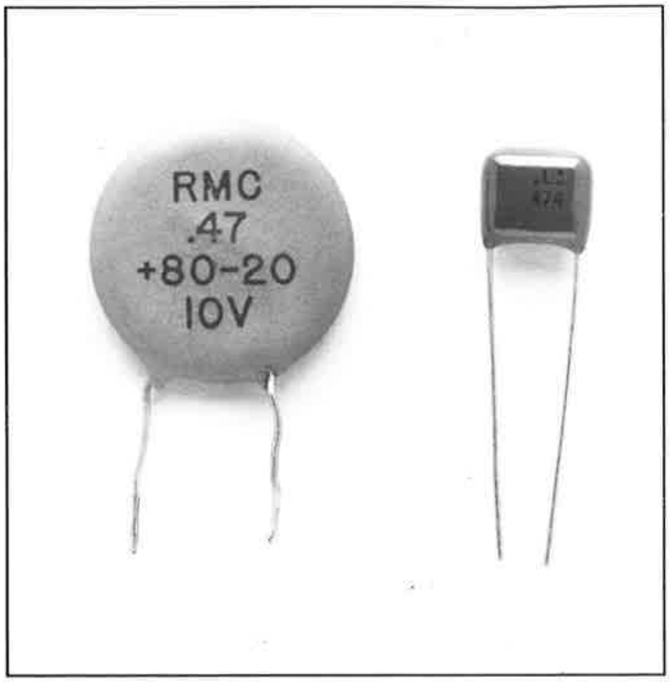


Fig. 38: Both capacitors have the same .47 uF value. The disc on the left is only rated at 10 volts, while the monolithic on the right is rated at 50 volts.

Some monolithic capacitors change value drastically with changes in applied DC voltage. The test voltage applied by the Z Meter value test causes the monolithic to increase to its highest value. This normal action may cause the capacitor to read up to 50% higher on the Z Meter than on a bridge which tests with an AC signal.

The Z Meter value readings are much more indicative of the way the capacitor acts in the circuit. Almost all capacitors operate with some DC bias. The only time the bridge value test agrees with the value the capacitor exhibits in the circuit is when the capacitor is used in a strictly AC application.

Temperature Characteristics

Ceramic capacitors can increase, remain the same, or decrease with a change in temperature. If a ceramic disc is marked with a letter P such as P100, then the value of the capacitor will increase 100 parts per million per degree centigrade increase. If the capacitor is marked NPO or COG, then the value of capacity will remain constant with an increase in the temperature.

Ceramic disc capacitors marked with an N such as N1500 will decrease in capacity as the temperature increases. The negative temperature coefficient is important in many circuits such as the tuned circuits of radio and television IF stages. The temperature coefficient of an inductor is positive and the inductance will increase as the temperature rises. If the tuning capacitor across the coil is a negative coefficient, then the net result will be a zero or very little change.

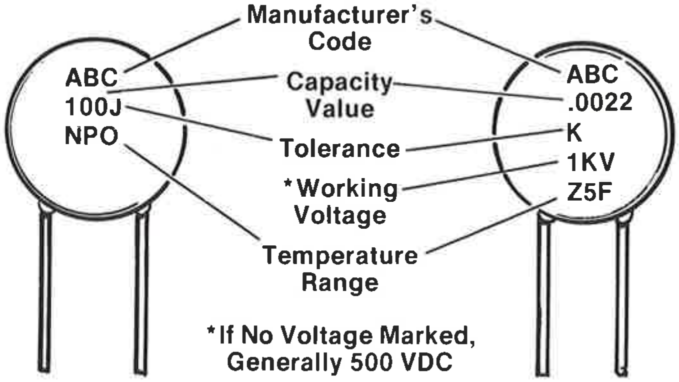
General type ceramic discs are often marked with such letters as Z5U, Z5F, Y5V, X5V, and so forth. This indicates the type of temperature curve for the particular capacitor. Ceramic capacitors that are not NPO or rated with N or P type characteristics will have wider temperature variations and can vary both positive and negative with temperature changes. The Z5U probably has the greatest change and will only be found in non-critical applications such as B+ power supply decoupling. These types of capacitors should not be used in critical applications such as oscillator and timing circuits.

You can quickly determine the basic temperature characteristics of a ceramic capacitor using your Z Meter and a heat source, such as a heat gun. Simply connect the capacitor to the Z Meter and measure the capacitance value while you apply heat to the capacitor. A COG or NPO type will change very little in value, if any, when heat is applied. An N type ceramic capacitor will decrease in value, while a P type ceramic will increase in capacitance.

A ceramic capacitor marked GMV means that the value marked on the capacitor is the guaranteed minimum value of capacity at room temperature. The actual value of the capacitor can be much higher. This type of capacitor is used in bypass applications where the actual value of capacity is not critical.

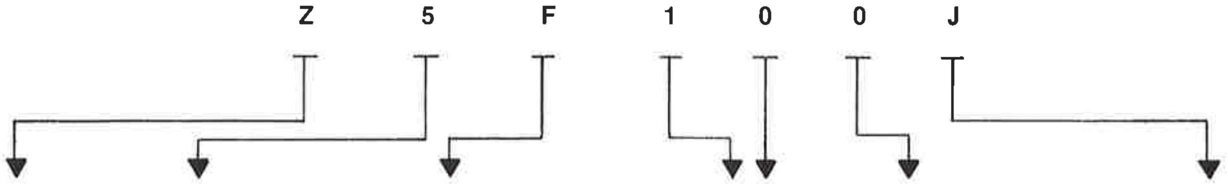
Ceramic capacitors have been the most popular capacitors in electronics because of the versatility of the different temperature coefficients and the cost. When replacing a ceramic disc capacitor, be sure to replace the defective capacitor with one having the same characteristics and voltage rating.

Ceramic Disc Capacitors



*If No Voltage Marked, Generally 500 VDC

Typical Ceramic Disc Capacitor Markings



Low Temp.	Letter Symbol	High Temp.	Numerical Symbol	Max. Capac. Change Over Temp. Range	Letter Symbol
+10°C	Z	+45°C	2	+1.0%	A
-30°C	Y	+65°C	4	±1.5%	B
-55°C	X	+85°C	5	±1.1%	C
		+105°C	6	±3.3%	D
		+125°C	7	±4.7%	E
				±7.5%	F
				±10.0%	P
				±15.0%	R
				±22.0%	S
				+22%, -33%	T
				+22%, -56%	U
				+22%, -82%	V

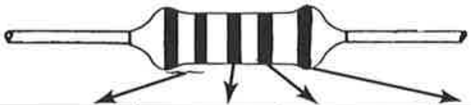
Temperature Range Identification of Ceramic Disc Capacitors

1st & 2nd Fig. of Capacitance	Multiplier	Numerical Symbol	Tolerance on Capacitance	Letter Symbol
	1	0		
	10	1		
	100	2	±5%	J
	1,000	3	±10%	K
	10,000	4	±20%	M
	100,000	5	+100%, -0%	P
		—	+80%, -20%	Z
		—		
	.01	8		
	.1	9		

Capacity Value and Tolerance of Ceramic Disc Capacitors

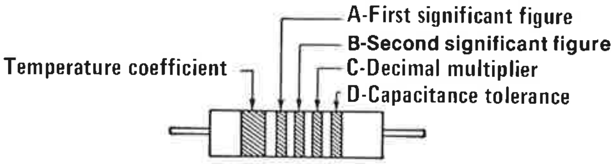
Fig. 39 : Use these charts to help identify markings on ceramic capacitors (more on page 40).

5 Band Ceramic Capacitors
(all bands equal size)



color	1st, 2nd Band	Multiplier	Tolerance	Characteristic
Black Brown	0 1	1 10	±20% (M)	NPO Y5S
Red Orange	2 3	100 1K		Y5T N150
Yellow Green	4 5	10K	N330	N220
Blue Violet	6 7			N470 N750
Grey White	8 9		±30% (N) SL (GP)	Y5R
Gold Silver	- -	0.1 0.01	±5% (J) ±10% (K)	Y5F Y5P

5 Dot or Band Ceramic Capacitors
(one wide band)

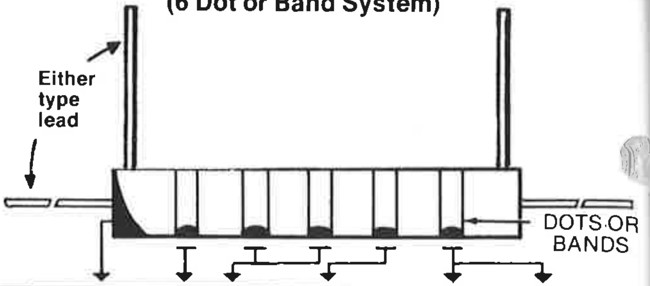


Fixed ceramic capacitors, 5 dot or band system

Color Code for Ceramic Capacitors

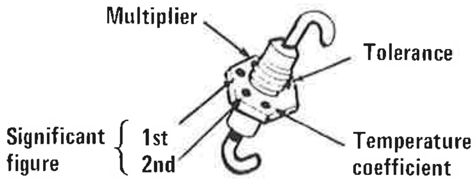
Color	1st & 2nd Significant Figure	Multiplier	Capacitance Tolerance Over 10 pF	Capacitance Tolerance 10 pF or Less	Temp. Coeff.
Black Brown	0 1	1 10	± 20% ± 1%	2.0 pF	0 N30
Red Orange	2 3	100 1000	± 2%		N80 N150
Yellow Green	4 5				N220 N330
Blue Violet	6 7		± 5%	0.5 pF	N470 N750
Gray White	8 9	0.01 0.1	± 10%	0.25 pF 1.0 pF	P 30 P500

Radial or Axial Lead Ceramic Capacitors
(6 Dot or Band System)



Temp. Coefficient T.C.	Temp. Coefficient 1st Color	Temp. Coefficient 2nd Color	Capacitance 1st and 2nd Sig. Fig.	Capacitance Multiplier	Capacitance Color	Nominal Capacitance Tolerance 10 pF or Less	Nominal Capacitance Tolerance Over 10 pF	Nominal Capacitance Tolerance Color
P100 P030	Red Green	Violet Blue	0 1	1 10	Black Brown	± 2.0 pF ± 0.1 pF	± 20% ± 1%	Black Brown
NP0 N030	Black Brown		2 3	100 1,000	Red Orange		± 2% ± 3%	Red Orange
N080 N150	Red Orange		4 5	10,000	Yellow Green	± 0.5 pF	+ 100% -0% ± 5%	Yellow Green
N220 N330	Yellow Green		6 7		Blue Violet			Blue Violet
N470 N750	Blue Violet		8 9	.01 .1	Gray White	± 0.25 pF ± 1.0 pF	+ 80% -20% ± 10%	Gray White
N1500 N2200	Orange Yellow	Orange Orange						
N3300 N4200	Green Green	Orange Green						
N4700 N5600	Blue Green	Orange Black						
N330 ± 500	White							
N750 ± 1000	Gray							
N3300 ± 2500	Gray	Black						

Ceramic Feed Through Capacitors



Color	Significant Figure	Multiplier	Tolerance 10 pF or Less	Tolerance Over 10 pF	Temperature Coefficient
Black Brown	0 1	1 10	2 pF 0.1 pF	20% 1%	0 N30
Red Orange	2 3	100 1,000	— —	2% 2.5%	N60 N150
Yellow Green	4 5	10,000 —	— 5 pF	— 5%	N220 N330
Blue Violet	6 7	— —	— —	— —	N470 N750
Gray White	8 9	0.001 0.1	0.025 pF 1 pF	— 10%	P30 + 120 to -750 (RETMA) + 500 to -330 (JAN
Gold Silver	— —	— —	— —	— —	P100 Bypass or couplin

All Other Caps (mica, film, paper, etc.)

	Value	Leakage	DA	ESR
All other caps (paper, film,mylar, etc.)	x	x	x	

- **Test for value, leakage, and dielectric absorption.**
- **Common failures: Short and leakage.**

The final capacitor type is the "all other capacitor" category. As the name implies, capacitors that fall under this category do not have the same electrical or physical characteristics to fit into any of the other capacitor types.

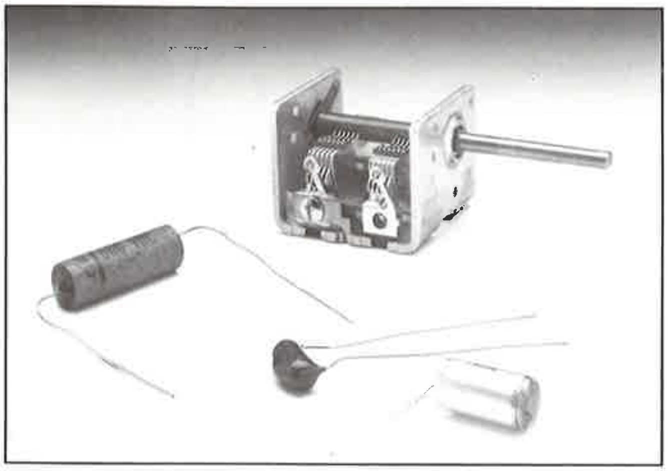


Fig. 40: "All other caps" include paper, mica, poly, air, and any capacitor with similar testing characteristics.

Capacitors included in this grouping are films, micas, air dielectrics, and paper types. Film type capacitors include mylar, polyester, polycarbonate, polystyrene, and polypropylene. The most common failures with these types of capacitors is a total short or leakage.

Though each of these capacitor types have different dielectrics and somewhat different parameters, they are all similar in that when tested with a Z Meter, they should have no dielectric absorption or leakage. Because of their relatively low capacitance value, ESR is of little importance and is not measurable. If you measure any leakage or dielectric absorption on any of these types of capacitors, the capacitor is bad.

Questions & Answers

How does an AC motor start (oil-filled) capacitor test with a Z Meter?

- **Self-healing.**
- **Only perform value test.**

Oil-filled AC capacitors are generally used in AC circuits such as motor start circuits. This type is basically an oil-filled self-healing non-polarized electrolytic that is used in AC circuits.

Since these capacitors are used with an AC voltage, the DC tests of the Z Meter are not applicable. The only test that means anything on AC capacitors is the capacitor value test. The capacitor value test is done similarly to an aluminum electrolytic's value test. The value may read a little high, but should never read much lower than the marked value.

Can Z Meters test chip capacitors?

Yes. Chip capacitors test the same as any other capacitors. They still must pass the Z Meter tests, whether the chip capacitor is ceramic, tantalum, or whatever.

The only difference is the packaging. The capacitors are so small, that the Z Meter conventional test leads may be too bulky to connect onto the capacitor ends.

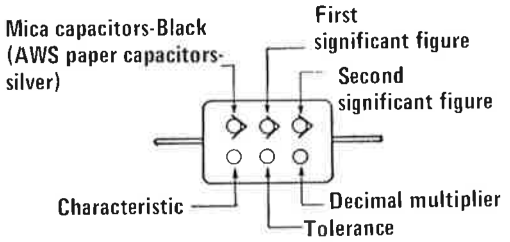
The optional CH256 test leads are designed especially for testing chip capacitors with a Z Meter. They are designed like a tweezer so you can hook onto the chip capacitor without fear of slipping off. Chip capacitors test just like other capacitors, so the capacitor must be tested out-of-circuit for accurate test results.

How do I test variable (trimmer) capacitors with my Z Meter?

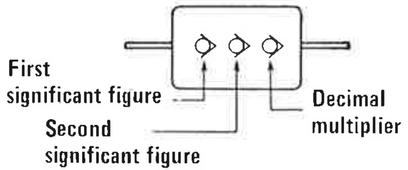
Easy. Just hook up the leads to the variable capacitor, and monitor the capacitance value while you adjust the capacitor from minimum to full range. The value should vary the full range of the specified value. There should be no point in the entire range where the value dips or drops out completely unless that is the design of the variable capacitor.

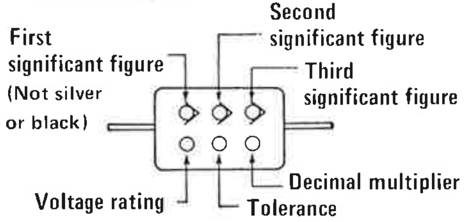
When the capacitor is turned to full value, perform the other Z Meter tests that are applicable to this type of capacitor. If any of these tests fail, the capacitor is bad.

Postage Stamp Mica Capacitors

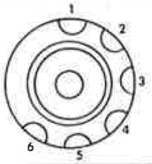


AWS and JAN fixed capacitors
(First dot silver or black)





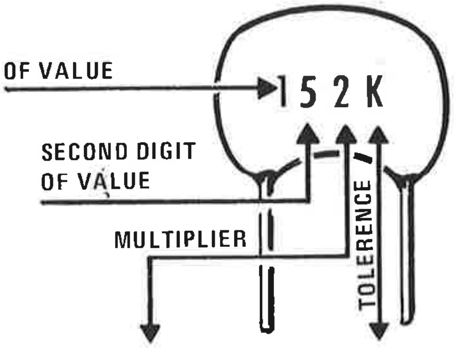
Standard Button Mica



1st DOT	2nd and 3rd DOTS		4th DOT	5th DOT		6th DOT
Identifier	Capacitance in pF		Multiplier	Capacitance Tolerance		Temp. Characteristic
	Color	1st & 2nd Sig. Figs.		Percent	Letter Symbol	
Black	Black	0	1	± 20%	F	
	Brown	1	10	± 1%	F	
NOTE: Identifier is omitted if capacitance must be specified to three significant figures.	Red	2	100	± 2% or ± 1 pF	G or B	
	Orange	3	1000	± 3%	H	
	Yellow	4				+ 100
	Green	5				
	Blue	6				-20 PPM/°C above 50 pF
	Violet	7				
	Gray	8				± 100 PPM/°C below 50 pF
	White	9	0.1			
	Gold			± 5%	J	
	Silver			± 10%	K	

Color	Significant Figure	Multiplier	Tolerance (%)	Voltage Rating
Black	0	1	–	—
Brown	1	10	1	100
Red	2	100	2	200
Orange	3	1,000	3	300
Yellow	4	10,000	4	400
Green	5	100.000	5	500
Blue	6	1,000,000	6	600
Violet	7	10,000,000	7	700
Gray	8	100,000,000	8	800
White	9	1,000,000,000	9	900
Gold	–	0.1	5	1000
Silver	–	0.01	10	2000
No color	–	—	20	500

Film Type Capacitors



MULTIPLIER		TOLERANCE OF CAPACITOR		
For the Number	Multiplier	Letter	10 pF or Less	Over 10 pF
0	1	B	± 0.1 pF	
1	10	C	± .25 pF	
2	100	D	± 0.5 pF	
3	1,000	F	± 1.0 pF	± 1%
4	10,000	G	± 2.0 pF	± 2%
5	100,000	H		± 3%
		J		± 5%
8	0.01	K		± 10%
9	0.1	M		± 20%

EXAMPLES:
152K = 15 x 100 = 1500 pF or .0015 uF, ± 10%
759J = 75 x 0.1 = 7.5 pF, ± 5%

NOTE: The letter "R" may be used at times to signify a decimal point; as in: 2R2 = 2.2 (pF or uF).

Fig. 41: Use these charts to help identify markings on these types of capacitors.

A capacitor tested good on my Z Meter. I replaced it anyway and it fixed my problem. Did my Z Meter miss a problem?

Probably not. If you had put the questionable capacitor back in circuit, it probably would have fixed the problem, too. Several things could cause the problem to mysteriously disappear.

Sometimes the physical doings of replacing a capacitor can require a lot of reorganizing and maneuvering. This movement could temporarily repair a physical intermittent or dislodge some foreign matter causing a circuit problem. When you power the circuit back up, the problem may appear to be fixed by the new capacitor when the problem was actually caused by a physical intermittent.

A capacitor could have had a cold solder joint or a bad foil connection that was just plain hard to see. An ohmmeter may not find this type of problem either since you may be applying pressure to the trouble point which temporarily fixes the problem. Just applying fresh solder to the foil junctions may fix this type of problem.

The heat that is applied to the leads of a capacitor may fix an internal problem of the capacitor. For example, if the lead welds are corroded or intermittent, the heat from desoldering the capacitor may repair the capacitor enough so it tests good with the Z Meter. This "repaired" capacitor could now be placed back in circuit, and it may work for years.

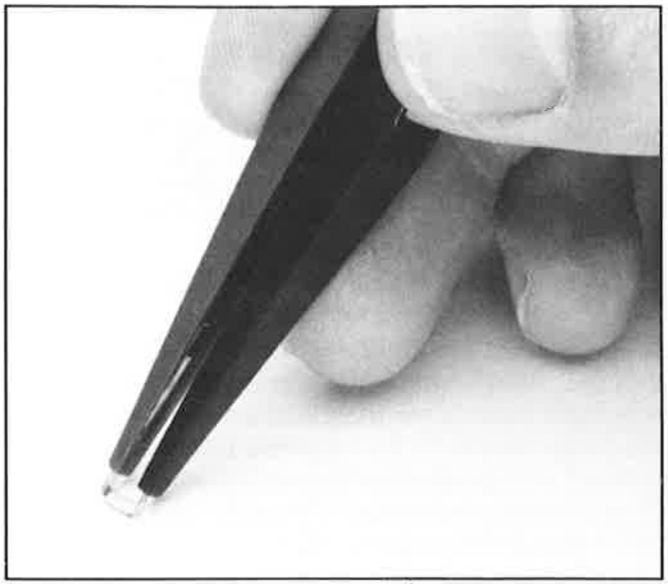


Fig. 42: Use the CH256 chip component test lead to test small chip capacitors out-of-circuit.

Inductors

The Inductor

Inductance is the ability of a conductor to produce induced voltage when the current varies. A long wire has more inductance than a short wire, since more conductor length cut by magnetic flux produces more induced voltage. Similarly, a coil has more inductance than the equivalent length of straight wire because the coil concentrates magnetic flux.

Components manufactured to have a definite value of inductance are just coils of wire, therefore, called inductors. Coils can be wound around hollow forms so that air is part of the magnetic circuit. Other coils are wound around iron cores. At the radio frequency range, air core inductors are used to reduce RF current. Iron-core inductors are used in the audio frequency range and lower frequencies in general.

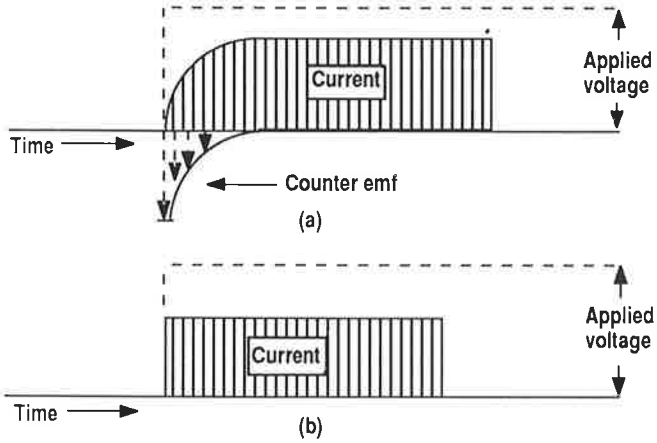


Fig. 43: Current, applied voltage, and counter emf plotted on a time base for (a) an inductive circuit and (b) a resistive circuit.

It is important to note that induction by a varying current results from the change in current, not the current value itself. The current must change to provide motion of the flux. A steady direct current of 1000 amps, as an example of a large current, cannot produce any induced voltage as long as the current value is constant. A current of 1 uA changing to 2 uA, however, does induce voltage. Also, the faster the current changes, the higher the induced voltage because when the flux moves at a higher speed, it can induce more voltage.

Since inductance is a measure of induced voltage, the amount of inductance has an important effect in any circuit in which the current changes. The inductance is an additional characteristic of the circuit besides its resistance. The characteristics of inductance are important in:

1. AC circuits: Here the current is continuously changing and producing induced voltage. Lower frequencies of alternating current require more inductance to produce the same amount of induced voltage as a higher-frequency current. The current can have any waveform, as long as the amplitude is changing.

2. DC circuits in which the current changes in value: It is not necessary for the current to reverse direction. One example is a DC circuit being turned on or off. When the direct current is changing between zero and its steady value, the inductance affects the circuit at the time of switching. This effect with a sudden change is called the transient response. A steady direct current that does not change in value is not affected by inductance, however, because there can be no induced voltage without a change in current.

The Units Of Inductance: Henry, mH, And uH

The unit for inductance is the henry (H), named after Joseph Henry. One henry is the amount of inductance that allows one volt to be induced when the current changes at the rate of one ampere per second. The formula for a self-induced voltage across an inductance L produced by a change in current di/dt can be stated as:

$$V_L = L\ di/dt$$

where V_L is in volts, L in henrys, and di/dt in amperes per second. This formula is just an inverted version of $L = V_L/(di/dt)$, giving the definition of inductance.

Since the henry is such a large amount of inductance, most inductances are referred to in terms of microhenry (uH) or millihenry (mH). These inductance terms are represented by the following numbers:

1 millihenry = 1 mH = 1 x 10^{-3} H
1 microhenry = 1 uH = 1 x 10^{-6} H

Most manufacturers don't mark inductors' values directly on the inductor package. Most inductors have a color code identifying its inductance on the inductor itself. The color code charts are included with the individual inductor types later.

Inductor Defects

Even though inductors are just a coil of wire with or without a core, they still can develop defects which will disrupt the circuit they are used in. Inductors usually develop four kinds of failures: value change, open coil, shorted coil, and shorted turns.

Value Change

Inductor static values are known to change from core breakage, windings relaxing, or shorted portions of the coil. An inductor that has changed value may adversely affect the circuit operation.

Open

An open coil breaks the circuit path and stops the current flow. The open may be caused by a physical intermittent, a manufacturing defect, or an excessive current flow causing the inductor to open. In any case, a coil with an open will act like an open circuit and cause an obvious change in the circuit's operation.

Short

A shorted coil essentially replaces the inductance of the coil with a piece of wire. Since a shorted piece of wire will not oppose any change in current or produce a reverse voltage, it will also greatly affect the circuit's operation.

Shorted Turn

Probably the most common problem with inductors is a single shorted turn. Coils are wound with insulated wire around some kind of a core, even air cores occasionally. If the insulation of two adjacent wires breaks down or melts, a shorted turn results.

When a coil develops a shorted turn, it no longer acts like a pure inductance. The shorted turn acts like a small secondary winding on a transformer. The short absorbs part of the stored energy and converts it to heat. This reduces the amount of current available for the load, which reduces the filtering.

A shorted turn has more effect with high frequency signals than with low frequency signals. The net result is loss of high frequency Q. When the coil is good, it has a high impedance to the ripple frequency. At lowered Q, it has less effect on high frequencies.

Z Meter Inductor Value Test

Sencore's Z Meters test for all coil and transformer defects in or out of circuit with the push of a button. The inductance value and ringing tests let you find inductor defects with dynamic and accurate results.

Inductor Value

- **Patented Test.**
- **Measures True Inductance.**
- **Test Is Not Frequency Dependent.**
- **Autoranged.**
- **Shorts And Opens Are More Common Than A Value Change.**
- **Flashing 8s Indicates An Open Coil.**
- **00.0 uH Indicates A Shorted Coil.**

The Z Meter measures true inductance, not inductive reactance as is done with impedance bridges. The Z Meter patented inductance value test 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 average value over the operating frequency range of the coil.

The Z Meter calculates the inductance and displays it directly in uH, mH, or H so you don't have to move decimal points or interpret the readings. The LC53, LC75, LC76, and LC101 measure inductance from 0.1 uH up to 9990 mH while the LC77 and LC102 measure all the way up to 20 H. If the inductance reading is not within the published specifications of the inductor, the inductor is bad and should be replaced.

Inductors do not change value very often. They may exhibit catastrophic failures such as totally open or shorted, but a change in static value is not that common. If an inductor has changed value, however, the Z Meter will show you the true value.

An open inductor will test like an open set of leads. When the INDUCTOR VALUE button is pushed, the display will flash 8s indicating an overrange condition. The LC77 and LC102 will show an OPEN indication on the display.

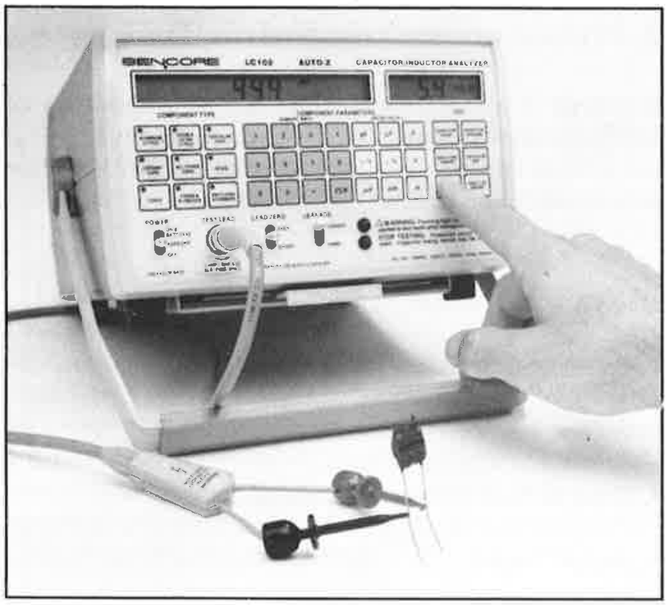


Fig. 44: The Z Meter measures inductance value and automatically autoranges it and displays the value along with the correct unit of inductance.

A shorted inductor will test similarly to a piece of wire on a properly zeroed Z Meter. The inductance test will give you results of 00.0 uH. If you do get a 00.0 uH inductance reading, check the marked value of the inductor. If the normal inductance is less than 10 uH, rezero the leads to assure that the Z Meter is zeroed properly. Otherwise, an inductor reading of 00.0 uH is an indication of a totally shorted coil.

Occasionally, an inductor will show an abnormal reading on the Z Meter display. These readings include a negative sign, a locked-up display, constantly changing readings, or a 1 followed by blank spaces. These readings indicate either a problem with the coil under test, or there is an external voltage present at the leads. If you are doing the test in-circuit, lift one leg of the inductor out of circuit. There may be voltages present because of charged capacitors bleeding off voltage. If the abnormal readings continue when performing the test out of circuit, the inductor either has an intermittent problem or the core has been damaged. In either case, the inductor is bad and should be replaced.

Comparing Z Meter Inductor Value To Bridge Readings

- **Bridge Measures Inductive Reactance, X_L**
- **Bridge Test Is Frequency Dependent.**
- **High Quality Coils Measure The Same With Either Method.**
- **Frequency Selective Coils Show The Widest Variation.**

Some inductors read differently for their inductor value on a Z Meter compared to a bridge or Q meter. The confusing part is that all of the readings are right, but still different. They're just using different methods.

The Z Meters measure inductance by applying a constantly changing current ramp through the coil and measuring the reverse EMF. This determines the inductance without reference to frequency.

A bridge (LCR, inductance, or impedance) determines the inductance by measuring inductive reactance at a single frequency, usually 120 Hz or 1 kHz. The formula for inductance reactance is:

$$X_L = 2\pi fL$$

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 a bridge, Q meter, or Z Meter. 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 highly permeable materials which produce very high inductance values in very small volumes, are often very frequency selective. Therefore, each method used to measure inductance produces a different value. Furthermore, the value measured with a 120 Hz bridge will be different than the value measured with a 1 kHz bridge. (Z Meter readings cannot be converted to bridge readings or Q meter readings or vice versa by use of a simple formula.)

The Z Meter gives you a second test for inductors, the ringer test. If the inductance value is important to you, you can compare the coil to a known-good one. Then you can set your standards for the good-cutoff point of inductance value.

Questions & Answers

How can I measure real small value inductors?

The resolution of Z Meters on small inductors goes all the way down to 0.1 uH, so just pushing the INDUC-

TANCE VALUE button on a properly zeroed Z Meter and reading the value will usually suffice.

However, if you need a more precise inductance reading, especially on inductors under 10 uH, you may want to manually offset the inductance zero control and subtract the offset reading from the measured value.

For example, if you offset the inductance zero to 2.0 uH and measure a coil to be 6.7 uH, the actual value of the inductor would be 4.7 uH. The offset (2.0 uH) subtracted from the measured value (6.7 uH) equals the actual value of the inductor (4.7 uH). This just allows for more precise readings without any chance of the Z Meter's zero window causing any inaccuracies. (This test can be performed on any Z Meter with a front panel zero control. The LC77 and LC102 have automatic zeroing circuits that will not allow you to offset the zero reading. However, by connecting the small inductor and zeroing the leads, you will see the inductor value on the display with a minus sign in front of it when when the leads are shorted during the inductance value test.)

Can I test the value of an inductor in-circuit?

Yes. You can use the Z Meter to measure the inductance of a coil with the component still in-circuit. In-circuit inductance measurements, however, may be affected by the impedance of the circuit. Low values of parallel resistance will lower the circuit impedance and cause the Z Meter to measure a lower inductance value. Figure 45 lists the amount of parallel resistance which will cause a 10 % or less change in the measured inductance. Resistances larger than the amounts shown will not have a significant effect on the inductance test. If there is a low impedance parallel resistance present, simply lift one side of the coil for proper test results.

How does the Z Meter compensate for DC resistance of an inductor?

After the current ramp is sent through the inductor during the inductance value test, the inductor is held in a quiescent state by a steady current. This steady current will produce a voltage drop across the coil. The Z Meter's patented circuits automatically subtract this voltage from the voltage developed across the coil with the current ramp.

Inductor	Value Minimum Parallel Resistance
1uH to 18 uH	10 to 100 ohms
18 uH to 180 uH	25 to 200 ohms
180 uH to 1.8 mH	50 to 500 ohms
1.8 mH to 18 mH	150 ohms to 1.3 k ohms
18 mH to 180 mH	400 ohms to 3 k ohms
180 mH to 1.8 H	800 ohms to 7 k ohms
1.8 H to 20 H	5k to 25 k ohms

Fig. 45: Inductors may be measured in-circuit if the parallel resistance is greater than the amounts listed here.

Can I test inductance value while the push-rod is holding in the inductance value button?

We don't recommend testing inductors using this method. When all of the Z Meter's buttons are in the "out" position, there is a low impedance path across the leads to discharge circuit capacitance voltage. When the INDUCTANCE VALUE button is depressed, the low discharge impedance path is bypassed which could allow a circuit voltage to damage the inductance measuring circuits. We recommend that you do not use the push-rod for inductance tests.

However, if you do use this method, make doubly sure that there is no chance of a voltage being induced into the inductance measuring circuits. The safest method is to measure inductors out-of-circuit.

Inductor Ringer

- **Hits Coil With Exciting Pulse And Counts Rings.**
- **Ringer Is Related To Q, But Not Equal.**
- **10 Rings Or More Is Good.**
- **Less Than 10 Rings Indicates A Bad Coil.**

The Z Meter's ringer test places a fixed capacitor in parallel with the inductor under test creating a tank circuit. Then it hits the tank circuit with a single exciting pulse causing the coil and capacitor to ring at their resonant frequency. The Z Meter's digital circuits count how many ringing cycles occur before the signal drops below a preset level.

A coil with high Q produces more ringing cycles than one with the same value and lower Q. A shorted turn in a coil drops the Q and therefore the ringing dampens out very quickly. Naturally, an open or completely shorted coil has very low Q also. Extensive research by Sencore's engineers has proved that the GOOD/BAD cutoff point for the number of rings for a good coil is 10. A coil that rings 10 times or more is good. A coil that rings less than 10 times is bad.

The Impedance Matching control lets you switch in different capacitors to be put in parallel with the

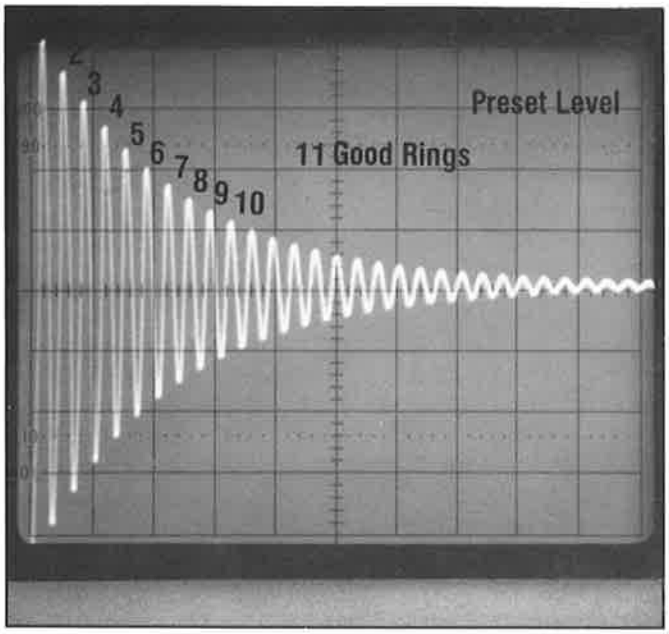


Fig. 46: The INDUCTOR RINGER test rings the coil with an exciting pulse and measures the resultant rings before the pulse deteriorates to a preset level. Ten or more rings indicates a good coil.

inductor under test. (The LC77 and LC102 perform the impedance matching automatically). If the ringing test yields a reading of 10 or more on any one or more of the Impedance Matching control switch positions for that type of coil, the coil is good. If all of the positions give a ringing reading of less than 10, the inductor is bad.

The Z Meter's ringing test will ring coils accurately all the way down to 10 uH. Coils smaller than 10 uH exceed the sensitivity of the Z Meter's measuring circuits.

Questions & Answers

Why does the ringing test find bad coils that other equipment can't?

A single shorted turn is one of the most common inductor failures but the hardest to detect. A shorted turn doesn't affect the resistance or the value of the coil enough to tell if the coil is bad. Most meters (value and ohms) don't have the resolution needed to show a single shorted turn.

The short does, however, reduce the quality of the coil enough to be detected by the ringing test. This effect is shown by a reading of less than 10. The ringing test is the only method that tests all three types of failures: an open winding, a completely shorted coil, and a single shorted turn.

What does the impedance matching control do?

The Impedance Matching control shown in figure 47 matches the test circuit impedance to the coil under test. The impedance works with the principles of resonance. If a capacitor and a coil are such that they have equal impedances, they oscillate when hit with an exciting pulse. The Impedance Matching control simply places different capacitors in parallel with the coil.

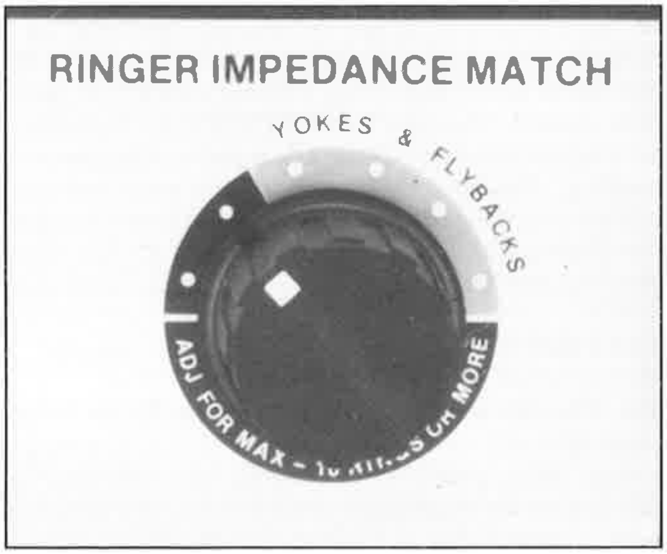


Fig. 47: The IMPEDANCE MATCHING control switches different capacitors in parallel with the coil under test.

You must test a coil with all the different positions of the Impedance Matching control for that type of coil to see if any of the readings are 10 or greater. When doing the ringing test, you may notice that each individual impedance position gives a different number of rings. If one or more switch positions gives a reading of 10 or above, the coil has no shorts.

The Impedance Matching switch contains two different sections for testing two different types of inductors. The red section is for yokes and flybacks. The blue section is especially for smaller coils (all others). Since yokes and flybacks have different impedances, the Impedance Matching switch is able to simply switch in different values of capacitors for these components. Use the section of the switch that matches the type of inductor you are testing with your Z Meter.

Is the ringing test the same thing as Q?

Although the ringing test is an indication of the Q of a coil, it is not same as Q. The Q, or quality, of a coil is an indication of a coil's ability to produce a self-induced voltage in proportion to its resistance. Even though a coil with high Q will ring higher than a coil with low Q on a Z Meter, the ringing reading is just an indication of Q, and not an actual Q reading.

Why do my Z Meter ringing readings drop when I set the coil under test on a metal surface?

When you bring a coil near a metal surface such as setting one on top of a metal plate, the metal acts like a shorted turn and absorbs some of the ringing energy. Be sure to keep at least one inch of insulating material between the coil you are ringing and any metal surface that could affect the ringing test.

Testing And Identifying Different Inductor Types

There are many different types of coils used in consumer equipment today. Each type has certain properties that make it better suited for particular applications.

When troubleshooting a circuit, it is not important to know why a certain type of coil was chosen. It is best to simply replace the defective coil with a coil of the same type.

Fig. 48: Inductors come in many different shapes and sizes, all with different testing characteristics.

Because different inductor types have different testing characteristics, it is important that you know what type of inductor you are testing in order to know if the Z Meter test results are acceptable or not. Once you know the inductor type, it is also extremely helpful to know the normal testing characteristics of the coil.

Inductors are often named according to the type of core used, or how they are used. Some common inductors include the flyback transformer, the deflection yoke, iron core inductors, air core inductors, and ferrite core inductors.

This section is intended to help you identify the types of inductors and recognize the different Z Meter testing characteristics of each.

Flyback Transformers

- **Powdered-Iron Or Ceramic Core.**
- **Used At Higher Frequencies Than Normal Transformers.**
- **Shorted Turn Is Most Common Defect.**
- **Z Meter Detects Shorted Turns In Primary Or Secondary With One Connection.**
- **Ringing Reading Of 10 Or More Indicates A Good Flyback.**
- **Test In-Circuit Or Out-Of-Circuit.**
- **Disconnect Loads If Flyback Rings Bad In-Circuit.**

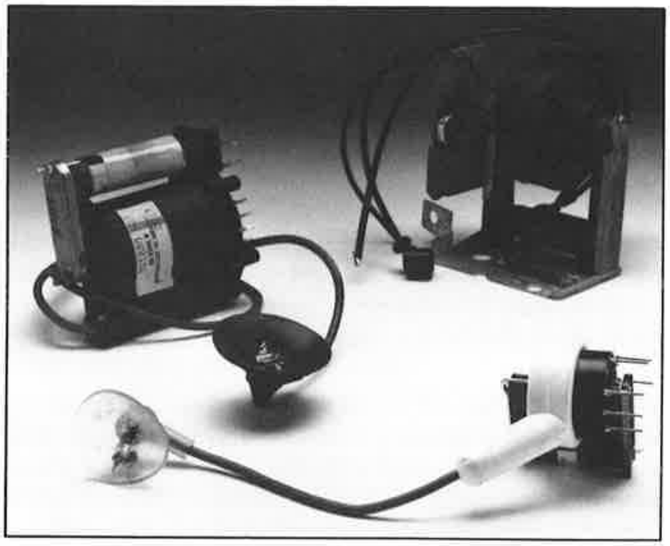


Fig. 49: Flyback transformers are easily identified by their shape and size.

A flyback transformer is a special type of transformer which produces the focus and second anode voltages for the CRT. The flyback bears little resemblance to the more conventional transformers found in other circuits, electrically or mechanically. Instead of a laminated iron-core for example, a flyback has a solid, powdered-iron or ceramic type of core to reduce losses due to the high frequency.

The flyback transformer has a number of special-purpose windings to feed a variety of diversified circuits. Unlike 60 Hz sine wave transformers, voltage turns ratios are not proportional because of the pulsed-waveform.

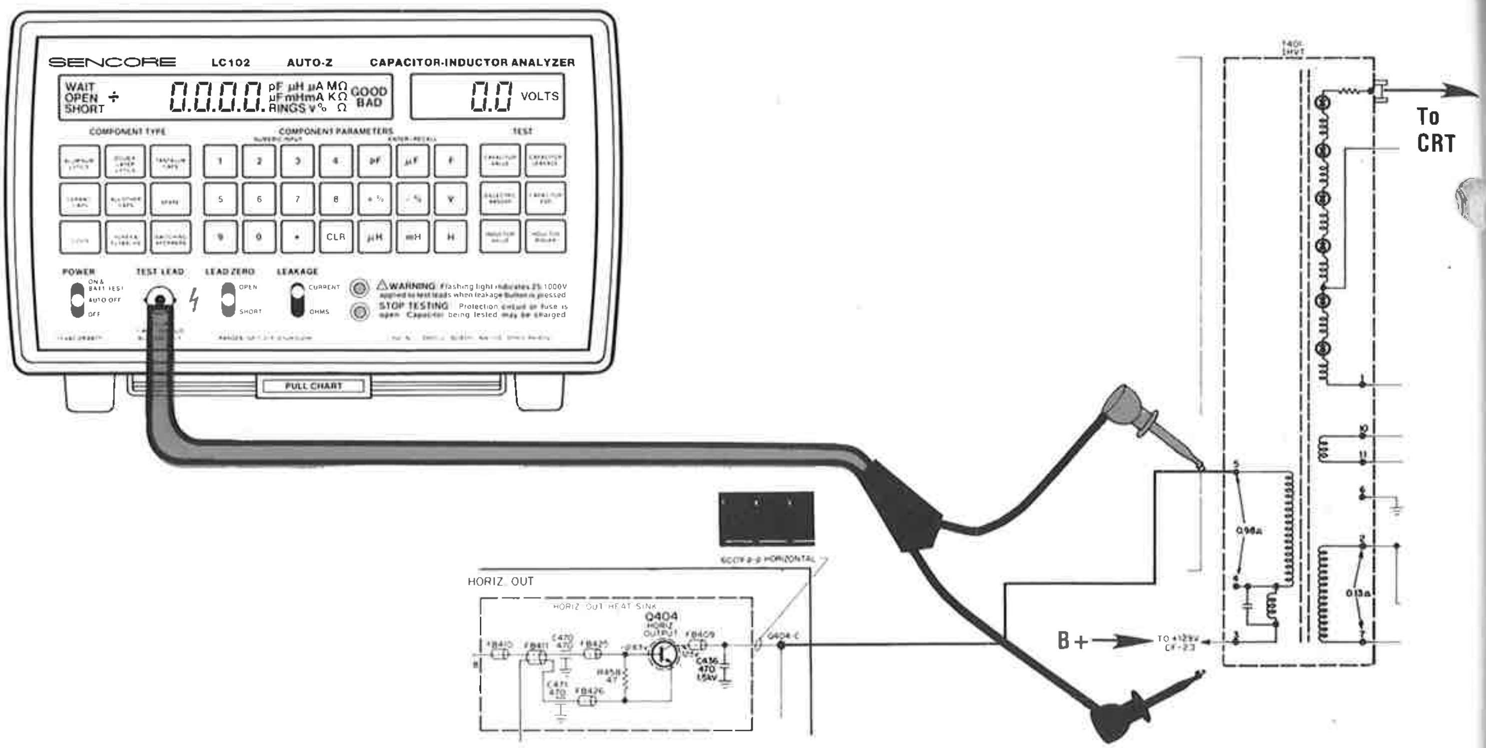


Fig. 50: The flyback winding between the horizontal output transistor and B+ is the best winding to use for the Z Meter's ringing test.

Many flybacks also have several lower voltage, relatively high current windings which power other circuits and the CRT filament. Because of the high voltages present, a flyback transformer may develop an internal shorted turn. A shorted turn reduces the efficiency of the transformer and usually causes severe circuit problems. Inductance measurements are of little value when troubleshooting a flyback since a shorted turn causes little change in inductance value. In addition, the normal inductance value is seldom known.

The Z Meter RINGER test will detect a shorted turn in any of the primary or secondary windings of a flyback. When you test a flyback with the Z Meter, you only need to make one set of lead connections to test all of the transformer windings.

You simply hook one Z Meter lead on the winding connected directly to the collector of the horizontal output transistor and the other lead to the other side of same winding (B+) as shown in figure 50. A reading of 10 or above proves that there are no shorts in the flyback, even in the secondary windings. The Z Meter RINGER test will detect a shorted turn in any of the primary or secondary windings of a flyback with this single connection.

A flyback may be tested in- or out-of-circuit with the Z Meter RINGER test, although several external loads may need to be disconnected before a good flyback will ring.

If the in-circuit test indicates a bad flyback, disconnect loads one at a time until the display reads a good reading. If the flyback suddenly rings good after disconnecting a load, check the load for a short as it may be loading the flyback down.

If the flyback still rings bad with all of the loads disconnected, the flyback is bad and should be replaced. If the Z Meter has an IMPEDANCE MATCHING switch, be sure to rotate the switch through all of the red YOKES & FLYBACKS positions and note the highest reading. If the highest reading is less than 10, the flyback is bad.

Questions & Answers

Will all windings on a good flyback ring good with my Z Meter?

No, but remember that you only need to get one winding to ring good with your Z Meter in order to prove a flyback good. A few flybacks used in some small solid state chassis have a low impedance primary which will not ring when good. However, these flybacks will always have a secondary winding which will ring good if the transformer is good. Simply ring the secondary windings. If any winding rings good, the flyback does not have any shorted turns. If all windings ring less than 10, the flyback is bad.

Some secondary windings or windings with only a few turns, such as CRT filament windings, may not have enough inductance for the Z Meter's ringing test sensitivity. In these cases, just use a different winding with more turns to ring the flyback.

Do I need to install the removable core in the flyback when I perform the ringing test?

Yes. Certain flybacks do have removable cores. The ferrite core and spacers must be installed inside the windings in order for the flyback to ring GOOD. Without them the flyback will always test bad. If a replacement flyback is the type that comes with the ferrite cores and mounting hardware, be sure to remove them from the chassis and install them on the flyback before performing the ringing test.

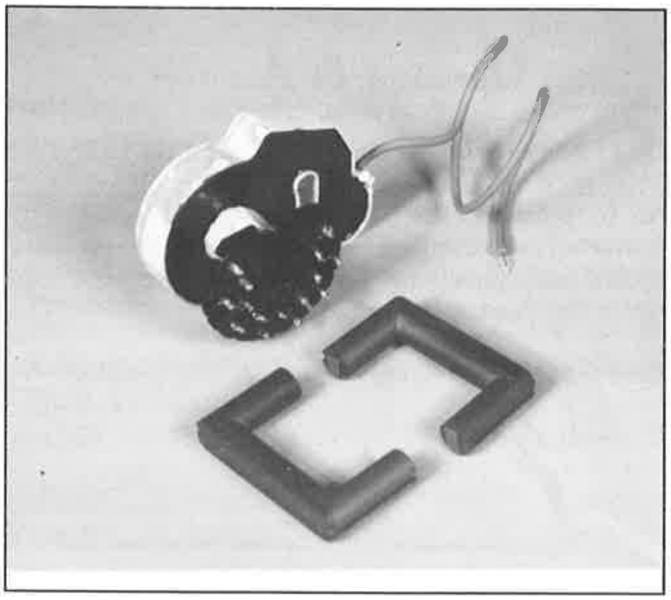


Fig. 51: The cores and spacers must be left in a flyback for it to ring properly.

If the flyback rings good, does that mean the flyback cannot have any other problems?

No. If the flyback rings good, you have proved that the flyback has no shorted turns in either the primary or secondary. However, there are some lesser common problems that will not show up with the ringer test.

Occasionally, a flyback winding will open up. A simple ohmmeter resistance test will find this type of problem. Or, you can use the ringing test to helpfind the problem. Simply hook the Z Meter leads to a winding that rings good and temporarily place a short across a different winding. If the Z Meter ringing reading still reads above 10, the winding with the temporary short across it is open.

If the winding with the short across it would be good, the Z Meter ringing reading would drop drastically to something less than 10 rings. This test just confirms that the ringing test will find a shorted turn anywhere in the flyback with just one connection. You can use this test to check for opens in all of the windings of the flyback by moving the temporary short to all of the other windings, one at a time and following the same procedure.

On rare occasion, the primary of a flyback will short to the secondary. In these cases, the ringer test will not show a problem since there is actually not a shorted turn in the flyback to dissipate the ringing pulse. A simple resistance check will confirm the primary to secondary short.

Will an integrated high voltage transformer (IHVT) test any differently than a regular flyback transformer?

An IHVT is a flyback and a high voltage multiplier built into one package. The same fundamentals of ringing a flyback transformer also apply to an IHVT. An IHVT can be identified by a lead leading to the second anode of the CRT.

The only thing different to keep in mind when ringing an IHVT is that a high voltage diode will act like an open circuit. The high voltage diodes in an IHVT are usually located in the secondary winding associated with the second anode lead. Since these high voltage diodes won't turn on until hundreds of volts are placed across them, the ringing test will see these diodes as open circuits. Just be sure to ring a winding that does not contain any high voltage diodes.

What kind of loads should I pull if the flyback does not ring good in-circuit?

You should always pull the easiest and most accessible loads first. These include the CRT filaments (just pull the socket off the CRT), the yoke (most yokes unplug easily), the horizontal transistor (mounted on the chassis), and any detachable plug that may be leading to a flyback winding. These loads are the easiest to disconnect plus they are the most likely to load the ringing test down in-circuit.

If the flyback still does not ring good after these loads are pulled, you need to pull the flyback completely from the circuit and ring it again. If it still rings bad out-of-circuit, the flyback is bad and should be replaced.

Does the TV need to be "On" when I ring a flyback?

No. No. No. The TV should be shut off. The ringing test is always performed with no power applied to the device under test. The ringing test applies its own pulse to the flyback and measures how it reacts to the pulse. As a precaution, the Z Meter input is fused to protect its circuits from damage.

Do I need to be concerned about the ringer polarity when testing flybacks?

Generally you can ring a flyback in either direction. To be doubly sure, however, reverse the polarity of the ringing leads and ring the flyback again. Sencore has found that the most reliable hookup for ringing flybacks is as follows:

> **red lead** - connect to primary winding connected to collector of horizontal output transistor
>
> **black lead** - connect to other end of same winding (generally the B+ connection)

Deflection Yokes

- **Deflects CRT Beam Vertically Or Horizontally.**
- **Has Two Separate Sets Of Windings - Vertical And Horizontal.**
- **Horizontal Windings Ring In Series Or Parallel.**
- **Vertical Windings Must Be Rung Separately.**
- **Damping Resistors Must Be Disconnected From Vertical Windings.**

Video deflection yokes are special inductors which are used to move a CRT electron beam both vertically and horizontally. As with flybacks, the Z Meter ringing test provides a quick and reliable good/bad test.

A deflection yoke has two sets of windings (horizontal and vertical) which must both test good. Both windings are in one package that slides on the back of a CRT to magnetically deflect the electron beam to help produce a picture.

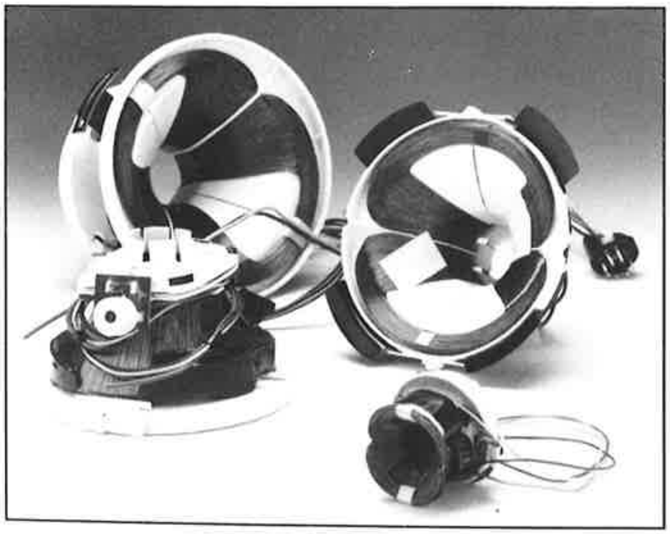


Fig. 52`: The easily recognized deflection yoke can be tested accurately with the Z Meter's ringer test.

The yoke leads generally terminate to a detachable plug which can be easily disconnected from the circuit. For a good deflection yoke, both the vertical and horizontal windings must ring at least 10 with your Z Meter.

The horizontal winding rings normally under virtually all conditions. Vertical windings, however, may have damping resistors across them which may affect the ringing test. If these resistors are mounted on the chassis, simply pulling the yoke plug will disconnect them. However, if they are connected directly to the yoke, you will need to unsolder one side of the damping resistor(s) for a proper test.

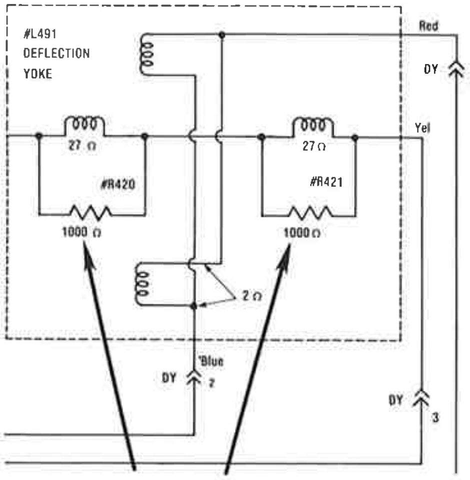
Questions & Answers

Do I have to take the yoke off of the CRT to test it?

No. In fact, it's best if you left it mounted on the CRT. A shorted yoke winding may be caused by the pressure of the yoke mounting. Relieving the pressure may cause the short to temporarily disappear.

Do I test yoke windings in series or parallel?

Horizontal yoke windings pose no problems. You can test them either in series or in parallel, both at the same time. A shorted turn in either one will show up on the ringer test.



Disconnect these damping resistors

Fig. 53: Disconnect the damping resistors if the vertical windings of a yoke ring bad. The damping resistors are low impedance paths that act like shorted turns.

Vertical windings should be tested individually, however. Simply unsolder and disconnect the common connection of the windings (remember to unhook the damping resistors). If the vertical yoke windings are in series, the windings should read within 3 rings of each other or the yoke may cause a problem in the chassis.

How do I find a defective yoke that has the vertical windings shorted to the horizontal windings?

With an ohmmeter. A quick resistance check is the fastest way to find this kind of problem.

You can use the Z Meter's leakage voltage to find leakage between windings however. There should be no leakage between windings on a good deflection yoke. Any leakage between windings indicates a high resistive connection or a short. A yoke with leakage between the horizontal and vertical windings is bad and should be replaced.

Switching Transformers

- **Wound On A Ferrite Core.**
- **Operates At Higher Frequencies Than Power Transformers.**
- **A Good Switching Transformer Will Ring Good With A Z Meter.**

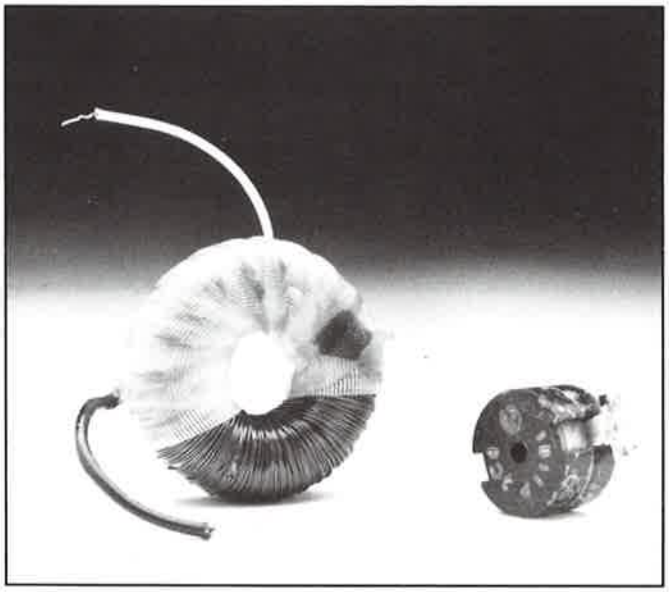


Fig. 54: Switching transformers come in a variety of shapes and sizes.

Switching transformers are used in power supply circuits to step voltages up or down. However, they are much different from conventional power transformers in both appearance and operation, and should not be mistaken for a power transformer. Power transformers usually operate at 60 Hz, and therefore contain a laminated iron core which is often visible. Because the iron core is low Q and absorbs all ringing energy, power transformers cannot be tested with the Z Meter's ringing test.

Switching transformers, on the other hand, are much smaller and lighter than power transformers. They are wound around a ferrite core which easily rings when good. Switching transformers operate at much lower currents and much higher frequencies than power transformers. A switching transformer that does not pass the Z Meter's ringing test is bad and should be replaced.

Iron-Core Transformers

- **Laminated Iron Core Acts Like A Shorted Turn.**
- **Most Iron Core Transformers Will Ring Less Than 10.**
- **Best Test Is Voltage In-Voltage Out.**

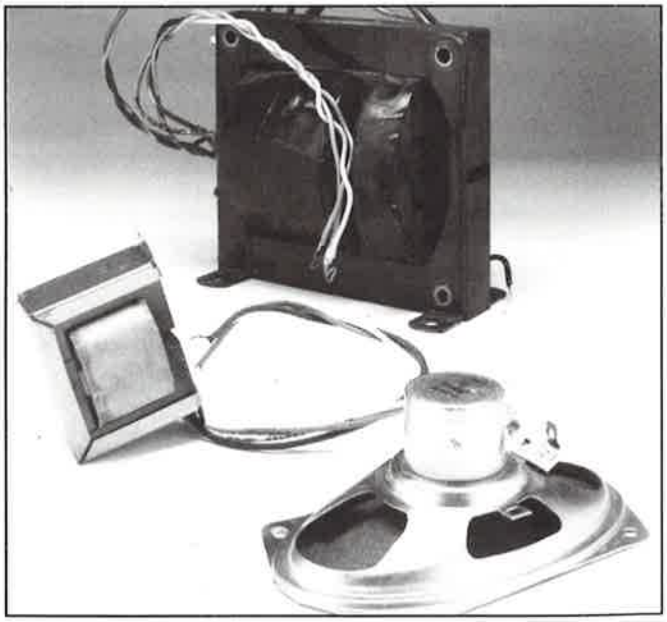


Fig. 55: Iron-core transformers normally ring low with the Z Meter.

Transformers such as power transformers and audio transformers contain laminated iron cores. Any coil with an iron core such as this will ring low with a Z Meter. The laminated iron core interrupts the magnetic field of the coil or transformer and acts like a shorted turn resulting in ringing readings of less than ten. If the transformer happens to ring 10 times or more, it is good. If it rings less than 10, however, you can compare the ringing reading to a known good transformer. If the ringing readings of the two transformers are comparable, then both are good.

If the suspect transformer rings considerably lower than the known good transformer, however, the suspect transformer has some kind of internal problem, probably a shorted turn. In this case, the transformer is defective and should be replaced.

Other types of iron-core inductors include isolation transformers, power chokes, filament transformers, motor coils, and speaker coils. The iron core material in all of these coils dampens the surrounding magnetic field and causes the ringing readings to be low.

Questions & Answers

Since laminated iron core transformers ring low, how do powdered iron or ferrite core transformers ring?

Transformers with powdered iron or ferrite cores do not dampen the ringing pulses, therefore they will ring normally with the Z Meter. Since they don't form a closed loop like a laminated iron core does, the magnetic field of the transformer is unaffected.

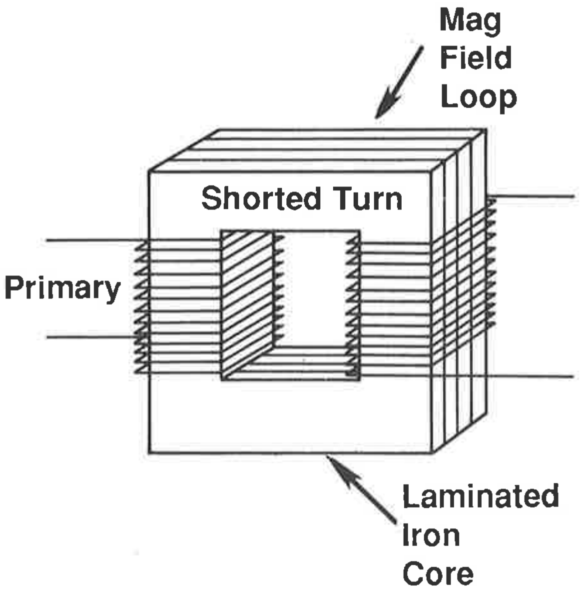


Fig. 56: The power transformer's iron core acts like a shorted turn which absorbs the ringing energy of the Z Meter's ringing test.

Can I perform the inductance value test on iron core transformers?

The Z Meter INDUCTANCE VALUE test will give you the relative value of iron core transformers, but normally this is not an important parameter. The most important factor of this type of transformer is whether or not it transforms a voltage properly.

What is the best test for iron core transformers?

The best way to test these types of transformers is to apply the normal working voltage to the primary, and measure the secondary(s) voltages with a voltmeter. You can also measure a power transformer's current draw under a no-load condition. If the current draw is near zero, there are no shorts in the transformer. If there is a heavy current draw, there is a short in the transformer.

All Other Types Of Coils

- **Perform The Ringing Test As Normal.**
- **Includes A Wide Variety Of Coils.**

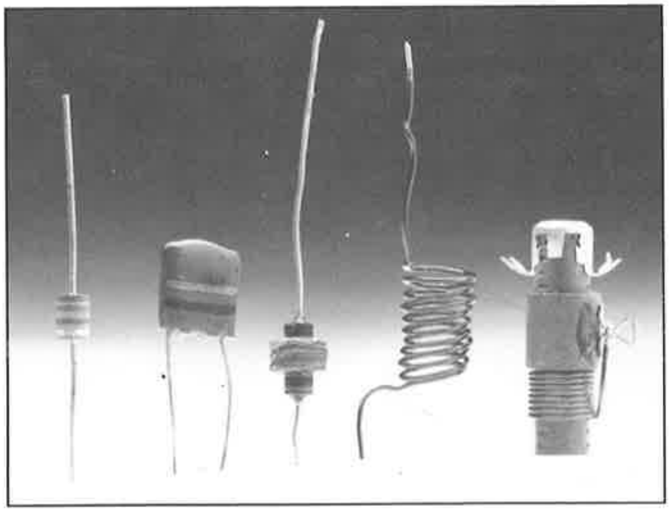
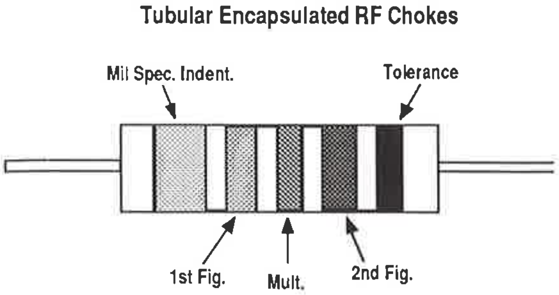


Fig. 57: All other types of coils should test for value and ringing normally.

All non-iron core inductors which cannot be classified as yokes, flybacks, or switching transformers are tested normally with the Z Meter ringing test. These include RF/IF transformers, RF chokes, postage stamp inductors, axial lead inductors, free form coils, as well as other assorted types. As long as the coil is at least 10 uH and does not have an iron core, the coil will ring normally.



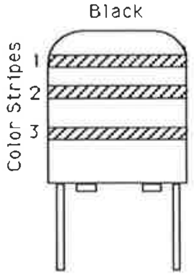
Color	Figure	Multiplier	Tolerance
Black	0	1	1
Brown	1	10	
Red	2	100	
Orange	3	1,000	
Yellow	4		
Green	5		
Blue	6		
Violet	7		
Gray	8		
White	9		
None			20%
Silver			10%
Gold			5%

Multiplier is the factor by which the two color figures are multiplied to obtain the inductance value of the choke coil in uH. Values will be in uH.

Fig. 58: Color code identification chart for tubular encapsulated RF chokes.

Toroidal Ferrite Coils

- **Uses Doughnut Shaped Ferrite Core.**
- **Permanent Magnetism May Cause Z Meter To Read Differently In Both Polarities.**
- **Demagnetize Coil Or Split The Difference Between Readings.**



" POSTAGE STAMP " FIXED INDUCTORS

Color	1st Digit 1st Strip	2nd Digit 2nd Strip	Multiplier 3rd Strip
Black or (Blank) 0	0	0	1
Brown	1	1	10
Red	2	2	100
Orange	3	3	1,000
Yellow	4	4	10,000
Green	5	5	100,000
Blue	6	6	
Violet	7	7	
Gray	8	8	
White	9	9	
Gold			x.1
Silver			x.01

Fig. 59: Color code identification for "postage stamp" fixed inductors.

A toroidal coil uses a doughnut shaped core of ferrite (powdered iron) material. The wires of the coil wrap around the core in one direction. The Z Meter may read the inductance value of these coils slightly higher with the test leads connected in one direction compared to the other. The amount of shift is minor; typically less than 5% from the value half way between the two readings.

This condition occurs because the Z Meter feeds a DC current ramp through the inductor and then measures the resulting EMF in order to calculate inductance. The highly permeable ferrite core may contain some permanent magnetism. This polarization normally results from prior use of the coil in a DC circuit or may even be the result of manufacturing processes.

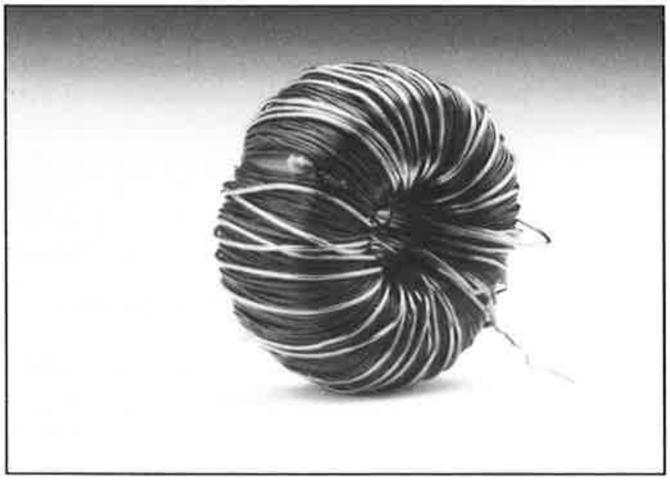


Fig. 60: Toroidal coils are wound on a ferrite core in the shape of a doughnut.

The residual magnetism causes a slight increase in the inductance value when the electro-magnetic field from the Z Meter current ramp opposes the polarity of the permanent magnetic field. The amount of value shift is generally so small that it can be ignored.

If you wish to eliminate the difference in readings, demagnetize the core using a demagnetizer designed for magnetic tape or tape recorder heads. Or measure the coil with the test leads in each direction and split the difference. For example, a coil measures 24.3 uH with test leads in one direction, and 25.7 uH with the leads reversed. The total difference between these two readings is only 1.4 uH. Subtracting half of this difference (0.7) results in a value of 25.0 uH

Video Heads

- **Soft Core Inductor.**
- **Inductance Is Normally Less Than 10 uH.**
- **Inductance Value And Ringer Tests Are Inconclusive.**
- **Signal Substitution Is The Best Method Of Testing.**

VCR video heads are a type of inductor. A video head consists of a core of "soft" ferrite material which has a coil of insulated wire wound around it.

You can check the inductance of the heads with your Z Meter. However, it is almost always less than 10 uH. This reading will tell you if the heads are open. Worn or shorted heads are harder to narrow down. Since heads do not always wear the same way, the inductance value of a worn head is not predictable. If a video head has shorted turns, the inductance value may change so little that an inductance value test may be inconclusive.

The ringer test is also an inconclusive test for video heads. Since the normal inductance value is less the Z Meter's ringer sensitivity, the reading will invariably be less than 10.

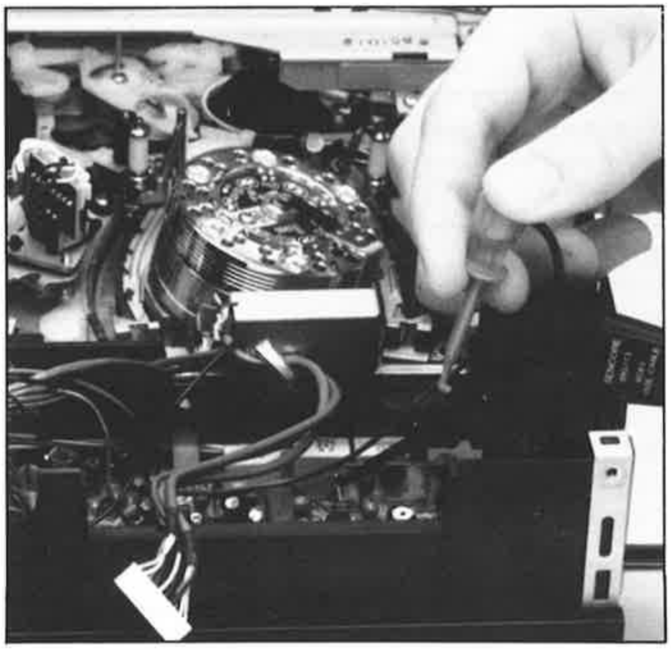


Fig. 61: The best test for video heads is signal substitution with Sencore's VC63 VCR Test Accessory

The best test for video heads is substitution with a known good signal using Sencore's VC63 VCR Test Accessory. If the substitute signal proves the remaining circuits good, the heads, along with the rotary transformers, are suspect.

Coils In Metal Sheilds

- **Metal Shield Absorbs Ringing Energy.**
- **Remove Metal Shield, If Possible, And Repeat Test.**

Sometimes coils, such as IF transformers, may be placed inside a shield to reduce in-circuit interference. These shielded coils may not ring good when tested with the ringing test because the metal shield absorbs some of the ringing energy.

A shielded coil is good if it rings 10 or more. However, if it rings less than 10, remove the metal shield, if possible, and test the coil again. If it now rings 10 or

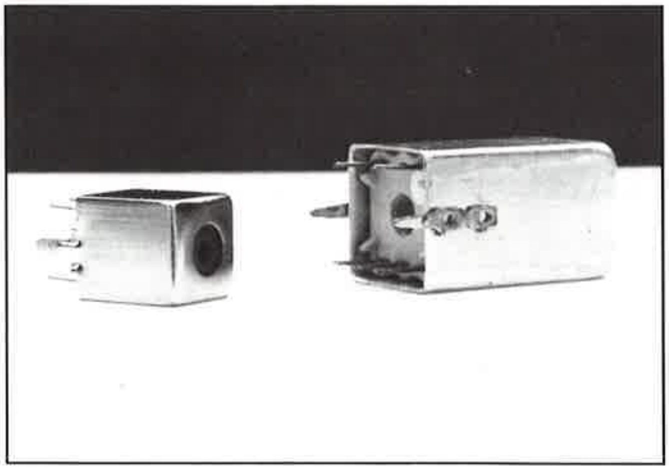


Fig. 62: If a coil in a metal shield rings bad with the Z Meter, remove the metal shield and ring it again. The metal shield may be absorbing the Z Meter's ringing energy.

more, the coil is good. If you are unable to remove the metal shield, make a comparison test using an identical, known good component.

Special Components And Special Tests

SCRs And Triacs

- **Used As Regulators And Controllers.**
- **Common Failures: Leakage And Inability To Turn On.**
- **Z Meters Along With SCR250 Test For Most Common Failures.**
- **Two Types Of SCRs: Sensitive Gate And Normal Gate.**
- **Flashing 8's Is Good For The Turn-On Test.**
- **Zero Is Good For The Leakage Test.**

SCRs and triacs are used in a variety of consumer and industrial applications. In consumer electronics, SCRs are found in television shutdown and regulator circuits. Triacs are often used in consumer products to turn AC line voltages on and off. In industry, SCRs and triacs are used as voltage regulators, controlled duty cycle rectifiers, and motor speed controls, as well as in other voltage control applications.

SCRs and triacs belong to a family of components called thyristors. A thyristor is a solid state device that is used as a switch. These solid state switching devices have become increasingly popular due to their long life and fast switching action.

An SCR is a three lead device that functions like a DC switch when given the proper control signal. An SCR has a cathode lead and an anode lead just like a standard rectifier. A third lead, called the gate lead, controls the operation of the SCR. Figure 63 shows the symbol used on schematics for an SCR. An SCR functions like an open circuit when it is "turned off" and like a diode when the SCR is "turned on". This SCR action is controlled by the signal applied to the gate lead. Notice that the symbol looks similar to a diode with the exception of the gate lead.

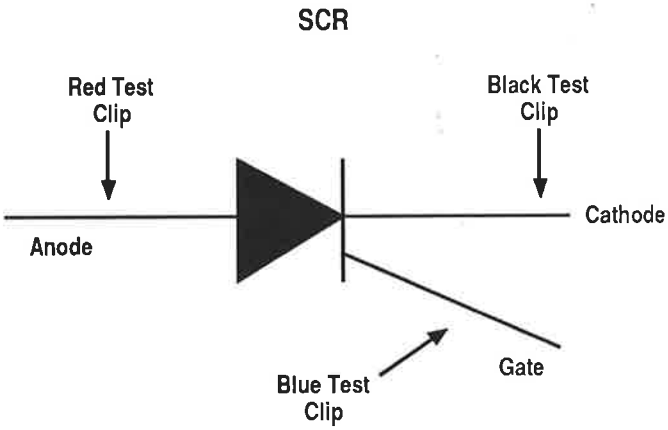


Fig. 63: Schematic symbol of an SCR with SCR250 test lead connections.

With no gate current applied to the gate lead, the SCR acts like a switch that is in the off position. When a sufficient gate current (trigger current) is applied, the anode-cathode junction is turned on and conducts current. Once the SCR is turned on, it continues to conduct current (latch), even if the trigger current is removed. The only way to turn an SCR off is to reduce the current flowing between anode and cathode below the holding current level.

SCRs are current-operated devices, so sufficient trigger and holding currents are much more important for SCRs to operate than are the voltage potentials applied to the terminals. Trigger currents vary from only 200

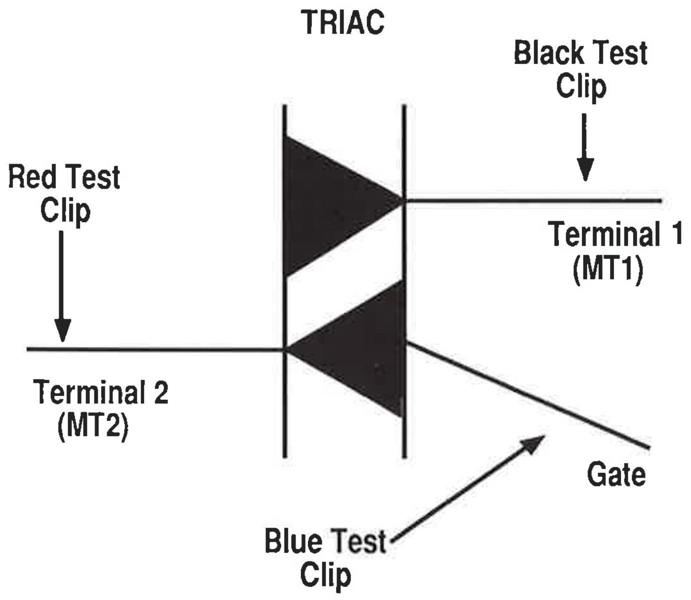


Fig. 64: Schematic symbol of a triac with SCR250 test lead connections.

SCRs to operate than are the voltage potentials applied to the terminals. Trigger currents vary from only 200 microamps in small SCRs to as high as 150 mA in industrial SCRs. These large SCRs may require 200 milliamps of holding current.

Triac Operation

A triac is a bi-directional device similar in operation to an SCR except that it passes current in both directions when "turned on". Figure 64 shows the schematic symbol for a triac. Note that the symbol resembles two diodes facing opposite directions. A triac has three leads labeled: Gate, MT1, and MT2. The gate lead performs the same function as the gate lead on an SCR: it turns the device on. The other two leads are labeled differently from an SCR because the function of these leads changes with the polarity of the voltage applied to the leads. The triac lead electrically closest to the gate lead is simply called the Main Terminal 1 (MT1), and the other lead is called the Main Terminal 2 (MT2).

How SCRs And Triacs Fail

An SCR or triac operates in one of two states: it is either on or off. In the off state, a properly operating SCR or triac blocks the flow of current through it. In the on state, a good SCR allows current to flow in one direction only. A good triac allows current to flow in both directions when it is turned on.

Common failures in SCRs and triacs are: 1. No turn-on, 2. Leakage or direct short, 3. Leakage at higher working voltages, 4. Triac only: Short in one direction; normal operation in the other direction.

SCRs and triacs fail to turn on when either the gate junction is damaged or the lead from the external connection to the gate junction is damaged. In either case, an external control voltage applied to the gate lead will not turn the device on resulting in no current flow.

Another common failure is leakage. The leakage through the SCR or triac may be of a low level or it may be large enough to act like a direct short. A leaky or shorted SCR or triac causes loss of control of the device it is connected to. Typical symptoms of a shorted SCR or triac are incorrect voltages in a regulator circuit or a motor controller that allows the motor to run at full speed with little or no control of the speed.

The third failure occurs when a relatively small amount of current flows through the SCR or triac only when a high voltage is applied between the main leads. This leakage current may be small or it may be so large as to act like a direct short. Low voltage tests of such an SCR or triac will indicate that the device is good. Only when a high voltage is applied will the device fail.

Triacs also exhibit a fourth type of failure. This failure results when the triac becomes shorted in one direction only. This type of failure allows current to flow in one direction, even when the triac is turned off. In the off mode, the defective triac acts like a diode.

Z Meter And SCR250 Tests For SCRs And Triacs

Any Sencore Z Meter, along with the SCR250 SCR and Triac Test Accessory, can be used to test SCRs and triacs. The Z Meter supplies the normal working voltage across the cathode and anode lead for an SCR, or across the MT1 and MT2 lead, for a triac. The high voltage checks for failures caused by leakage or a partial short. The Z Meter supplies a high enough voltage to locate SCRs and triacs that leak or short only at their working voltage. In addition, the Z Meter's digital meter monitors the amount of current flow through the SCR or triac. This measures the leakage current and also tells you when the SCR or triac is conducting.

The SCR250 provides a controlled gate signal to the SCR or triac. The SCR250 allows you to safely apply the gate signal to the device under test by giving you the

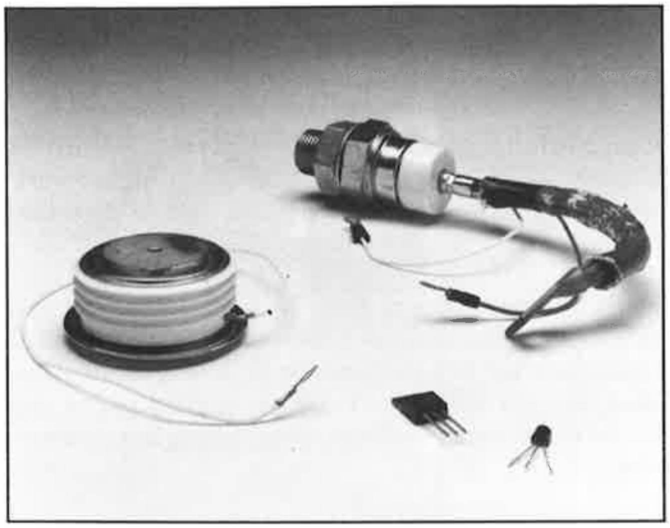


Fig. 65: SCRs come in many different shapes and sizes, but can be classified into one of two kinds: normal gate or sensitive gate.

choice of applying a gate signal for either sensitive SCRs or larger SCRs. The SENSITIVE GATE position of the SCR250 applies a smaller signal to the SCRs gate to prevent damage on more sensitive SCRs. The NORMAL GATE position applies a larger signal to turn on the larger SCRs.

SCR Types

SCRs come in a variety of sizes, shapes, current ratings, and voltage ratings. They can, however, all be classified into one of two types: sensitive Gate and normal Gate. Sensitive gate SCRs get their name from the fact that they are very sensitive to the current applied to the gate lead. They are typically used in low current applications where only a small gate control current is available. Sensitive gate SCRs come in a variety of physical shapes and sizes and cannot be easily distinguished by simply looking at them.

For many applications, sensitive gate SCRs, are too sensitive for reliable use. Internal currents in the SCR, or small currents in the triggering circuits, may accidentally cause these SCRs to "turn on." Heat can also cause internal leakage currents to rise to the point of "turning-on" the SCR. To prevent SCRs from accidentally "turning-on", many of them have an internal bleeder resistance built into them. This bleeder resistance is placed between the gate and cathode lead as shown in figure 66. The resistance bleeds off any internal currents that might build up and prevents the SCR from accidentally "turning-on" by itself. Due to the internal resistance, these SCRs require a higher external gate current to turn them on. In most applications, this additional gate current is easily obtainable, thus these SCRs have become more popular than the sensitive gate type and are called "normal or standard gate SCRs."

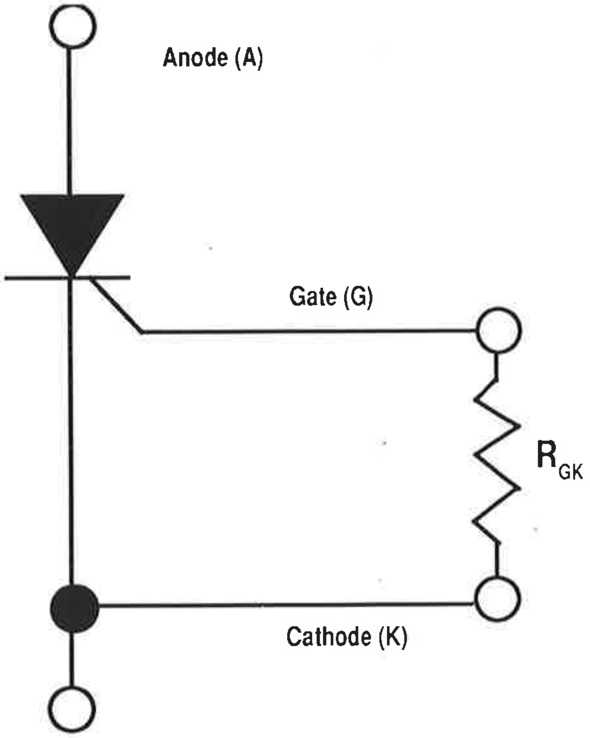


Fig. 66: SCRs with an internal bleeder resistor, R_{GK}, require a larger external gate current to turn them on.

Questions & Answers

What if I don't know if the SCR I'm testing is a sensitive gate type or a normal gate type? Which range do I use on the SCR250?

Whenever you don't know what type of SCR you are testing, start out on the SENSITIVE GATE position. If the SCR turns on in this position, it is capable of turning on. If it does not turn on, use the NORMAL GATE position. This range will turn on the vast majority of SCRs in use today. If the SCR still does not turn on, either the SCR is defective or the SCRs turn on current is higher than the SCR250 can supply.

When I perform a test with the Z Meter and SCR250, do I need to hold the leakage button in or will one push of the button do the test? How long should I hold it in?

You must hold the Z Meter's leakage button in when you perform either a turn-on test or a leakage test. The leakage voltage is only present when the leakage button is pushed, so either test will not be performed if the leakage button is not pushed in.

For either the turn-on or leakage test, you only need to hold the leakage button in for two or three updates of the Z Meter's display, generally less than 5 seconds. The readings will change very little after this, so the component's condition can be determined from the first few readings you see.

What kind of readings should I expect for a good SCR or Triac?

Simple. You should see flashing 8's for the turn-on test. You should see a zero reading for leakage.

Flashing 8's tells you that the component is turning on. Any numerical reading other than flashing 8's means the SCR is not turning on properly. Examples of bad readings for bad SCRs include anything from 1 to 9990 uA or even a reading of zero. A reading of zero means the component is not turning on at all; it is acting like an open circuit.

A good SCR or triac should result in a leakage reading of zero. Some good SCRs or triacs may give a very small leakage reading due to the resistance of the case materials or normal anode-cathode leakage. As a general rule, anything less than 10 uA leakage is considered good.

What leakage range should I set my Z Meter to?

Set the LEAKAGE RANGE switch to LARGE ALUM ELECTROLYTICS when performing tests on SCRs and triacs. The ALL OTHER CAPACITORS range gives you more resolution on the leakage test, but the readings may be confusing since you can see smaller leakage currents. The smaller leakage currents are of no concern when testing SCRs and triacs.

The LC53, LC75, LC76, and LC101 Z Meters are equipped with this capacitor leakage range switch. The LC77 and LC102 leakage tests are autoranged: all of the ranging is performed internally by the microprocessor.

How do I determine what voltage to set the Z Meter at?

SCRs and triacs typically do not have their working voltage stamped on the case as do capacitors. Furthermore, their working voltage is generally not listed in the parts list of the instrument. The working voltage can often be determined by one of the following methods.

A good indication of the rated voltage of the SCR or triac can be obtained by looking at the operating voltage of the circuit that the device is used in. For example, if the SCR or triac is used to switch AC line power, the device must be able to withstand the full peak-to-peak voltage of the line. This requires a device having a rated working voltage of at least 400 volts. An SCR used in the regulator section in a television horizontal output section must have a rating of at least 400 to 500 volts to withstand the reverse voltage from the flyback. Small SCRs used in hold down circuits, for example, typically operate from a 24 volt B+ supply and usually have a working voltage rating of 50 volts or more.

The best way to determine the operating voltage of an SCR or triac is to cross the device over to a substitute type using a substitution guide for semiconductors. The working voltage of the substitute SCR or triac is equal to or higher than the working voltage of the device you are testing.

There are occasions when the SCR or triac to be tested is not listed in a substitution guide and no circuit voltages are available. In these cases, set your Z Meter to 25 volts and perform the turn-on test. If the component does not test good, increase the voltage setting of the Z Meter and test it again. Continue to increase the Z Meter voltage until the component tests good. Then perform the leakage test using the same voltage. If the component won't turn on at the high voltage setting, it is either defective or the turn-on level is too high for the SCR250.

What does it mean when I get a reading like "8790" or "7630" when I perform the turn-on test?

One of two things. The SCR may be defective. Most likely, though, the turn-on current for the device is larger than the SCR250 can supply. Even if the SCR250 can't turn the device on, the Z Meter will still read the leakage current running through its leads. The resultant leakage is a result of normal gate-cathode leakage telling you that the device has not turned on. When in doubt, compare the SCR to a known-good one.

How does the SCR224 differ from the SCR250?

The two are essentially the same except the method they use to turn the SCR or triac on. The SCR224 uses the leakage voltage of the Z Meter to turn the device on while the SCR250 has its own battery supply for turn-on. The SCR250 has the advantage, though, since it can supply more current than the Z Meter leakage supply can.

How do I test 'Hockey Puck" SCRs?

One of the most common industrial SCRs is commonly called the "hockey-puck" SCR. The hockey-puck SCR gets its name because of its shape as shown in figure 67. Hockey-puck SCRs test similarly to regular industrial SCRs except for a few differences.

Fig. 67: The "hockey puck" SCR gets its name because of its shape.

Many hockey-puck SCRs are pressurized. A pressurized SCR will not turn on until a pressure is applied to the SCR plates. Until these plates are compressed, the gate will remain open at all times. All you need to do is apply pressure to both plates of this type of SCR when testing it with your Z Meter and SCR250.

Typically, hockey-puck SCRs are very high-powered devices. If testing the SCR with the SCR250 and the Z Meter doesn't prove the SCR good, you'll want to keep a couple of things in mind.

Check the operating characteristics of the SCR. If the trigger current is more than the SCR250 can supply, the turn-on test will not turn the SCR on. However, the leakage test will find the majority of problems in this type of SCR. When in doubt, compare the SCR to a known good one.

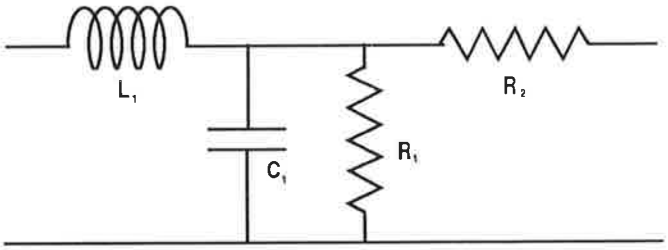
Cables

- **Every Cable Has Normal Capacitance And Inductance.**
- **Open - Measure Capacitance And Calculate Length To Fault.**
- **Short - Measure Inductance And Calculate Length To Fault.**
- **Use Leakage Voltage To Find Aging And Partially Shorted Cable.**

Coaxial cables and transmission lines have characteristics of both an inductor and a capacitor, as illustrated in figure 68. The Z Meter can be used to determine the length of a piece of coaxial cable (or the distance to a break) and the distance to a short between the center conductor and shield. Any breakdown in the dielectric can also be detected using the Z Meter's leakage power supply.

A length of coaxial cable open at both ends is equivalent to a long capacitor, with the two conductors forming plates. Every type of coaxial cable has a normal amount of capacitance per foot, specified in picofarads per foot (pF/ft). The capacitance per foot values for some common coaxial cable types are listed in figure 69.

The length of a piece of cable, as well as the distance to an open, is found by simply measuring the capacitance between the center and outer conductors and dividing this total capacitance by the cable's capacitance per foot value. If possible, measure from both ends of the cable to more accurately pinpoint the break. In most cases, the length of a cable can be determined within 1-2 %.



L_1 = Series Inductance

C_1 = Shunt Capacitance

R_1 = Shunt Resistance (dielectric leakage)

R_2 = Series Resistance

Fig. 68: A length of coaxial cable consists of capacitance and inductance distributed throughout the cable's length.

A coaxial cable which has a short between its center conductor and outer conductor is similar to a very long inductor. The Z Meter can be used to determine the distance to a short using the INDUCTOR VALUE test. The amount of inductance per foot of a coaxial cable is not usually published by the cable manufacturer, and the amount for the same type of cable may vary significantly from one manufacturer to another. Therefore, to calculate the distance to a short you must first use a sample piece of cable to determine the normal inductance per foot. With that information, you can calculate the distance to the short.

50-55 Ohm

RG/U Cable Type	Nominal Impedance	Nominal Cap in pF/FT	Nominal Inductance
5B/U	50	29.5	
8U	52	29.5	
8U Foam	50	26	
8A/U	52	29.5	
10A/U	52	29.5	
18A/U	52	29.5	
58/U	53.5	28.5	
58/U Foam	50	26	
58A/U	50	30.8	
58C/U	50	29.5	
58C/U Foam	50	26	
74A/U	52	29.5	
174/U	50	30-30.8	
177/U	50	30	
212/U	50	29.5	
213/U	50	30.5	
214/U	50	30.5	
215/U	50	30.5	
219/U	50	30	
225/U	50	30	
224/U	50	30	

70-75 Ohm

RG/U Cable Type	Nominal Impedance	Nominal Cap in pF	Nominal Inductance uH/FT
6A/U	75	20	
6A/U Foam	75	20	
11U	75	20.5	
11U Foam	75	17.3	
11A/U	75	20.5	
12A/U	75	20.5	
13A/U	74	20.5	
34B/U	75	20	
35B/U	75	20.5	
59/U	73	21	
59/U Foam	75	17.3	
59/BU	75	20.5	
164/U	75	20.5	
216/U	75	20.5	

90-125 Ohm

RG/U Cable Type	Nominal Impedance	Nominal Cap in pF	Nominal Inductance uH/FT
62/U	93	13.5	
62A/U	93	13.5	
63B/U	125	10	
71B/U	93	13.5	
79B/U	125	10	

Fig. 69: Capacitance per foot values for common coaxial cable types.

Questions & Answers

Can you show me an example of how to find the distance to an open in a cable?

Let's use figure 70 as an example. There is an open in this 100 foot length of cable, type RG 59/U. First, you measure the capacitance on one end of the cable with your Z Meter and note the value. In this case, you measured 798 pF. Then you take the 798 pF and divide it by the normal capacitance per foot of the cable. This cable type is listed in figure 69 as having 21 pF per foot for its normal capacitance.

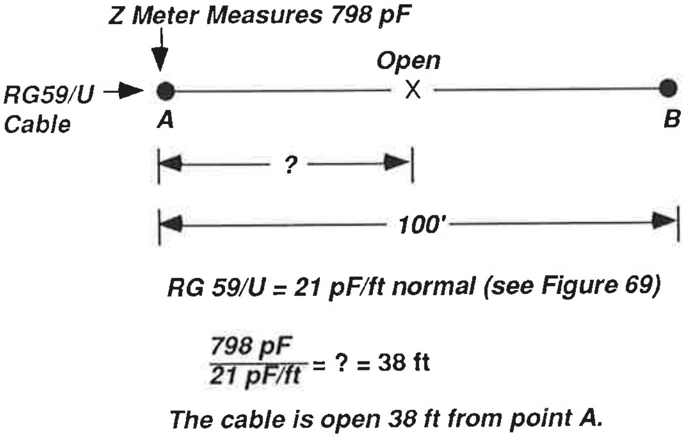


Fig. 70: You can find the distance to an open in a cable by dividing the total measured capacitance by the normal capacitance per foot of the cable. The result is the number of feet to the open.

The result of that division is 38. This means that there is an open about 38 feet from the end of the cable you are measuring. If you want to get even closer to the open, repeat the process on the other end of the cable. Then take the average of the two readings and use that measurement to find the open.

Now can you show me how to find a short in a cable?

Assume you're using the 250 ft. length of cable shown in figure 71. There is a short in it somewhere and you want to find it with your Z Meter. Start by measuring the inductance of one side of the cable. In this case, the Z Meter measures 632 uH.

Now you need to measure the inductance of a piece of sample cable to find the normal inductance of that

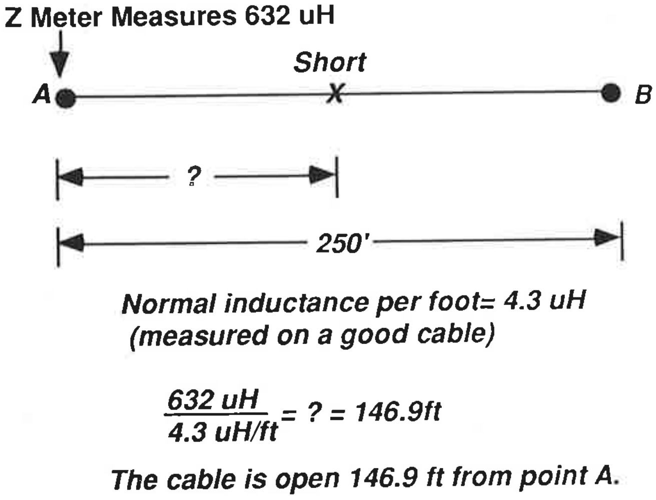


Fig. 71: You can find the distance to a short in a cable by dividing the total measured inductance by the normal inductance per foot of the cable. The result is the number of feet to the open.

cable. Let's assume you measured 215 uH on a 50 ft. piece of sample cable that you temporarily shorted on one side. Dividing the 215 uH by 50 ft. gives a normal inductance per foot of 4.3 uH.

Simply divide the total inductance measured, 632 uH, by the inductance per foot, 4.3 uH. This division yields a number of just under 147. This number simply states that the short is about 147 ft. from the end of the cable you are measuring from. You can get an even more accurate measurement by repeating the tests from the other end of the cable similarly to the capacitance tests made above.

How long of a length of cable do I need to measure for an accurate reading when determining the normal capacitance/inductance per foot?

Sample lengths of at least 10 feet are recommended for accurate capacitance measurements. A cable length of at least 25 feet is recommended for inductance measurements. The longer the piece of sample cable you use, the more accurate your measurements will be since you minimize variables such as length measurement errors and inconsistent cable parameters.

How do I find a partial short or a breakdown of the dielectric with the Z Meter?

You simply measure the leakage from the center conductor to the outer grounding shield of the cable. Make sure both ends of the cable are disconnected for accurate readings.

Most cables have a large maximum operating voltage. These cables should be tested with the Z Meter's leakage voltage set at maximum. A few "air space" dielectric types of coaxial cable, such as RG37, RG62, RG71, and RG72 have a maximum operating voltage of 750 volts and should be tested at this voltage.

A good piece of cable should have no leakage when the leakage voltage from the Z Meter is applied between the center conductor and outside shield. The length of the cable being tested will make no difference on the leakage reading. Any leakage reading indicates the dielectric is breaking down.

How do I find aging cable with the Z Meter?

All coaxial cables exposed to the elements eventually degrade to the point where they need to be replaced. The Z Meter can be used for preventative maintenance checks of coaxial cable to determine if deterioration is beginning to occur. As a cable begins to fail, the dielectric separating the conductors becomes contaminated causing a change in the cable's capacitance and the DC leakage through the dielectric.

All cable has a normal amount of capacitance per foot and any significant change that occurs over a period of time indicates a developing problem. The best check for aging cable is to measure and record the total capacitance of the installation when it is first installed. If the initial value is not known, you can multiply the length of the cable by its nominal capacitance per foot. Then compare periodic capacitance measurements back to the initial amount and look for any changes. As the dielectric becomes contaminated, the Z Meter capacitance reading will increase.

Will the Z Meter work on multi-conductor cables?

Much of the cable used today is multi-conductor cable, with or without a shield. The Z Meter locates opens and shorts in these cables, too. However, there are a few differences.

First, there are no standard capacitance or inductance per foot values for non-coaxial cables. This means that you will need to measure a sample length of cable. Secondly, multi-conductor cables are not as consistent as coaxial cable. Therefore, use as long a piece of sample cable as possible for the best accuracy.

Measurements on cables with less than four conductors are easily affected by noise and stray pick-up. On cables with four or more conductors, the Z Meter will locate the distance to the problem with an accuracy of between five and 10%. This is still within 10 feet out of 100 feet, however, which is as good as the best resolution offered by many of the other types of cable testers.

Finally, when testing multi-conductor cables without a shield, you must wrap all of the wires, except one, together to form a "shield". Once you have wrapped the wires together to form a shield, you test the cable using the same procedures used to test coaxial cable.

What do flashing 8's mean when I measure the capacitance of a cable?

Anytime you see a non-standard reading on either the capacitance or inductance tests on the Z Meter, it is indicating a problem in the cable. Some of these non-standard readings include: flashing 8's, blank display, locked-up display, and random or erratic readings. Performing the leakage test on these cables should eliminate any question as to their condition.

High Voltage Diodes

- **Can't Be Tested With An Ohmmeter.**
- **Z Meter's Leakage Voltage Makes Them Conduct.**
- **Flashing 8's For Normal Forward Conduction.**
- **Zero Leakage For Reverse Conduction.**

High voltage diodes, such as those found in video high voltage and focus voltage sections may require up to 200 volts before they are forward biased and begin to conduct. They cannot be tested with an ohmmeter since, with only a few volts applied, a good high voltage diode will simply indicate "open" no matter how the ohmmeter is connected.

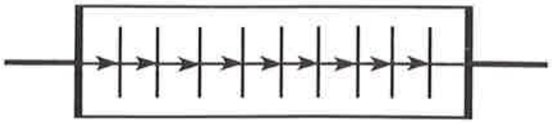


Fig. 72: To test a high voltage diode, enough voltage is needed to forward bias all the junctions.

The capacitor leakage test of the Z Meter provides sufficient voltage to bias high voltage diodes into conduction and also to test them for reverse breakdown. Test the diode for normal forward conduction first.

Then reverse the test leads and check for reverse leakage. A good high voltage diode will show zero leakage.

Questions & Answers

How do I know if the Z Meter has turned the high voltage diode on?

The Z Meter's display will flash 8's. You must check the diode in the reverse direction also, however, since a shorted diode will also flash 8's. A good diode should show zero leakage in the reverse direction.

Where do I set the Z Meter's leakage voltage if I don't know the voltage rating of the diode?

Set the Z Meter at 25 volts and perform the turn-on test. If the diode doesn't turn-on at 25 volts, increase the Z Meter's leakage voltage slowly until the diode does start to conduct. Then reverse the leads and check for reverse leakage at the same voltage.

What if I see a number reading on the Z Meter display rather than flashing 8's or zero?

If you are testing for normal forward conduction, increase the leakage voltage slightly. The Z Meter should start to flash 8's as it turns on the diode completely. If you cannot make the Z Meter's display flash 8's, the diode apparently has a defect in it and should be replaced.

If you are testing for reverse leakage, consider the diode bad and replace it.

Hi-Potential (Hi-Pot) Testing

- **Test For Leakage At High Voltage.**
- **PC Boards Should Show Zero Leakage Between Foils.**
- **Switch Contacts Should Have Zero Leakage.**
- **Transformers Should Have Zero Leakage Between Windings.**

The Z Meter can be used to locate leakage currents as low as .1 uA, such as the leakage between PC board foils, leakage between windings of a transformer, and leakage between switch contacts and shafts. These leakage currents are much to small to be measured with an ohmmeter, but are measurable when a high voltage potential (Hi-Pot) is applied with the Z Meter leakage power supply.

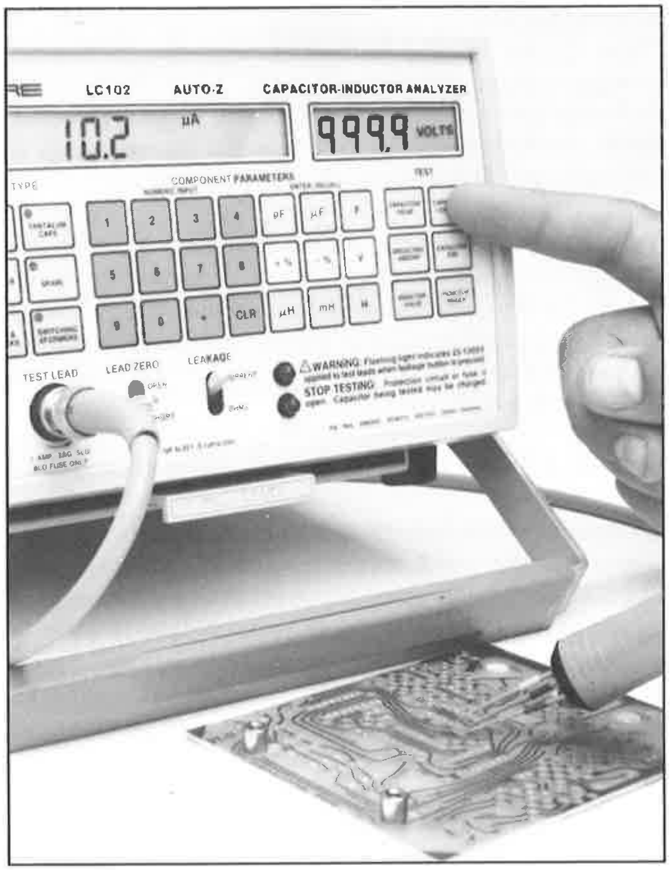


Fig. 73: Small leakage paths can be detected with the Z Meter Hi-Pot test.

Traces on a bare printed circuit board should show no leakage between them when tested at maximum voltage with the Z Meter. Any leakage indicates contamination on the board, or fine, hair-like projections from the etched traces shorting between the traces. The (optional) 39G85 Touch Test Probe may be used to make easy connection to the foils. It provides needle-sharp points that are adjustable for different trace settings.

AC power transformers can be tested to make sure they provide proper isolation from the AC line. Transformers should be tested for leakage between the primary and secondary, as well as for leakage between the windings and the metal core or frame. To test for leakage between primary and secondary, disconnect all transformer leads from the circuit. Connect one of the Z Meter test leads to one of the primary leads and the other Z Meter lead to one of the secondary leads. If the transformer has more than one secondary winding, each should be tested for leakage.

Most transformers used today have a 1500 volt breakdown rating and should have zero microamps of leakage when tested at full voltage with the Z Meter. Any leakage indicates a potential shock and safety hazard.

Measuring Resistors

- **LC77 And LC102 Read Out Directly In Ohms.**
- **Measures Resistors From 100 Ohms To 1 Gigohm.**
- **Leakage Voltage Must Fall In Shaded Area On Graph.**

Focus and high voltage resistors up to 1 gigohm may be measured using the leakage power supply in the LC77 and LC102. These Z Meters will read the resistance of these resistors directly on the LCD display without any calculations. The other Z Meters do not have a resistance function to directly display the resistance value.

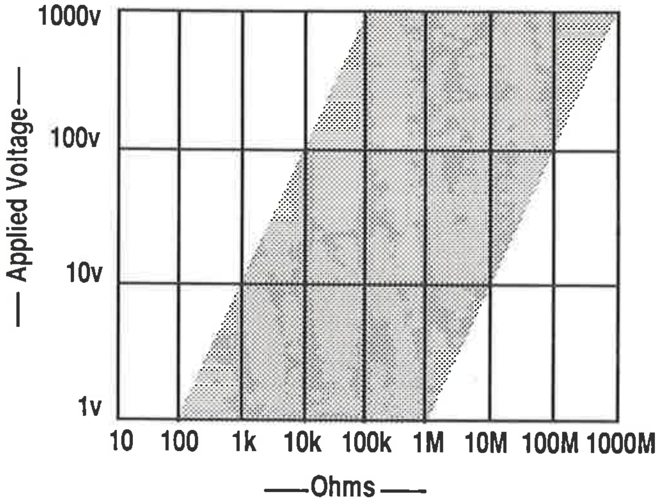


Fig. 74: To measure resistance values up to 1 gigohm, enter the necessary leakage voltage to place the resistance value within the shaded area.

These resistors are often much too large in value to be measured with any other test.

The range of resistance which the LC77 and LC102 will measure depends on the applied voltage. Figure 74 shows the amount of applied voltage needed to produce a usable resistance reading. The Z Meter will measure resistors from 100 ohms to 1 gigohm, but the voltage used on the Z Meter must fall in the shaded area. By placing the front panel LEAKAGE switch in the OHMS position, the Z Meter will display the amount of resistance directly in ohms.

Questions & Answers

What happens if I don't use a voltage in the shaded area of the graph?

For the smaller resistors on the left side of the graph, the Z Meter will not produce enough current to give an accurate value. On this side of the graph you will have to turn the Z Meter leakage voltage down to obtain an accurate reading.

For the larger resistors on the right side of the graph, the Z Meter's microprocessor will make the display overrange if there is not enough voltage chosen for the resistance value you are measuring. Simply increase the voltage value until it falls within the gray area of the graph.

Applications Of The Leakage Power Supply

- **LC76, LC77, And LC102 Are DC.**
- **Power Supplies Are Current Limited.**

Many times a variable voltage DC power supply is needed in troubleshooting and other applications such

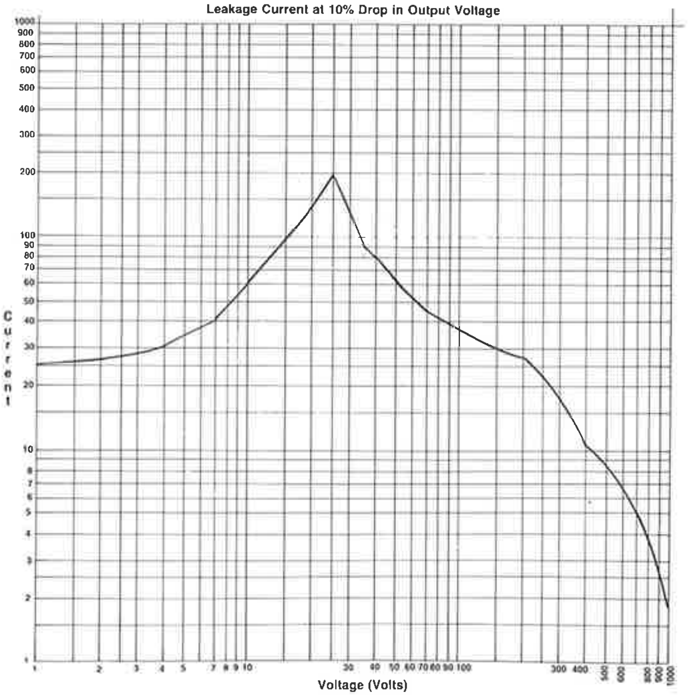
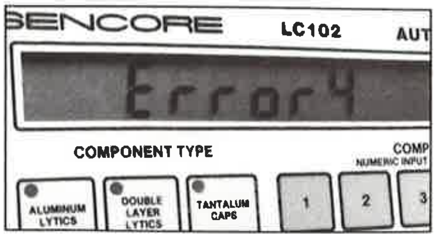


Fig. 75: The LC77 and LC102 power supplies provide current outputs from 2 to 200 mA, depending on the voltage selected.

as applying a bias voltage or powering a circuit. The LC76, LC77, and LC102 leakage power supplies may be used in these applications to provide these DC voltages. The LC53, LC75, and LC102 leakage power supplies are a pulsated DC derived from the AC line, so their use is much more limited.

The amount of current being drawn by the circuit connected to the Z Meter will be displayed in the LCD display. The LC76 will display up to 10 mA while the LC77 and LC102 will display up to 20 mA. Current greater than this will cause the LCD display to overrange.

The leakage power supply is current limited and will not be damaged by excessive current draw. When overloaded, the output voltage will drop to a level that will not damage the supply. Tech Tip #112 covers the most common uses of the Z Meter power supplies.



Miscellaneous Information

Error Codes

Several error conditions may occur while using the LC77 or LC102 which cause an error message to appear in the LCD display. These are usually caused by small errors in the operation of Z Meter, although severely defective components may also cause certain error conditions. The error conditions are explained below:

Error 1 - Component Type Selection Error

This error occurs when a component test is attempted, and either an incorrect COMPONENT TYPE switch is selected for the test, or no COMPONENT TYPE switch is selected when required.

Possible causes:

1. Performing a capacitor test with an inductor COMPONENT TYPE switch selected.
2. Performing an inductor test with a capacitor COMPONENT TYPE switch selected.
3. Performing the INDUCTOR RINGER test without an inductor COMPONENT TYPE switch selected.
4. Performing any component test with the SPARE capacitor COMPONENT TYPE button selected.

Error 2 - Entered Value Beyond Range Of Unit

The component parameter entered via the keypad or IEEE is beyond the measuring range of the Z Meter.

Possible causes:

1. Entering a capacitance value greater than 19.9 Farads, or less than 1 picofarad.
2. Entering an inductance value greater than 19.9 Henrys, or less than .1 microhenrys.
3. Entering a leakage voltage greater than 999.9 volts.
4. Entering a tolerance percentage greater than +100%, or less than -99%.
5. Entering a tolerance percentage that includes a decimal.

Note: *Entering a leakage voltage less than 1 volt will set the leakage supply to 0 volts.*

Error 3 - Entered Value Beyond Range Of Test

The component parameter entered via the keypad or IEEE is beyond the limits of the automatic good/bad test. The component may still be able to be tested, but not for a good/bad indication.

Possible causes:

1. Performing an ESR test with a capacitor value of less than 1 uF entered.
2. Performing a D/A test with a capacitor value of less than .01 uF entered.
3. Performing an INDUCTOR RINGER test with an inductor value of less than 10 uH entered.

Error 4 - Value Beyond Zeroing Limit

The amount of inductance or capacitance at the TEST LEAD INPUT is beyond the range of the zeroing circuits. An open (greater than 20 Kilohms) or shorted (less than 1 ohm) test lead will cause the "OPEN" or "SHORT" annunciator to come on, rather than produce an "Error 4".

Possible causes:

1. The capacitance at the TEST LEAD INPUT is greater than 1800 pF.
2. The inductance at the TEST LEAD INPUT is greater than 18 uH.
3. The resistance at the TEST LEAD INPUT is greater than 1 ohm.

Error 5 - No Voltage Entered

This error occurs when the CAPACITOR LEAKAGE button is pushed and no test voltage has been entered.

Error 6 - Invalid IEEE Command

An improper command was sent to the Z Meter via the IEEE bus.

Possible causes:

1. Sending a command that is not recognized by the Z Meter.
2. Wrong command syntax.

Note: Refer to the IEEE 488 Bus Option section of the operator's manual for information on using the Z Meter with IEEE control.

Error 7 - Component Out Of Test Range

The component under test exceeds the limits of the test which was attempted.

Possible causes:

1. Measuring ESR of a capacitor having a value less than 1 uF.
2. Measuring capacitance value on an extremely leaky capacitor.
3. Attempting a capacitor value test with 1 ohm to 2 megohms of resistance connected across test leads.

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