WARNING!!

DISCONNECT all power to equipment under test and DISCHARGE the capacitors before using this device! Failure to do so may damage the Capacitor Wizard®, equipment under test, and ***could be hazardous to the operator***. Damage caused by attempts to use this device on powered up equipment or charged capacitors is NOT covered by the Warranty!

Battery Replacement

Remove the 4 screws from the bottom of the Capacitor Wizard®. Replace with 4 size AA Alkaline Batteries.

Specifications

Battery operation - 6vdc: 4 AA Alkaline Batteries
Supply Voltage 4vdc to 6vdc
Power drain 30ma @6vdc
Battery life 60-80hours
Battery low @4.0v
Open circuit probe voltage: <15mv Peak to Peak (<5mv rms)
Test Signal: 100Khz Sine Wave
Input resistance : 2.5 ohms
ESR range: 0 to 30 ohms expanded scale

CE

Environmental operating conditions: Indoor Use. Altitude to 2000M. Temperature 5 deg C to 40 deg C. Maximum relative humidity 80% for temperature up to 31 deg C decreasing linearly to 50% relative humidity at 40 deg C. Pollution Degree 2.

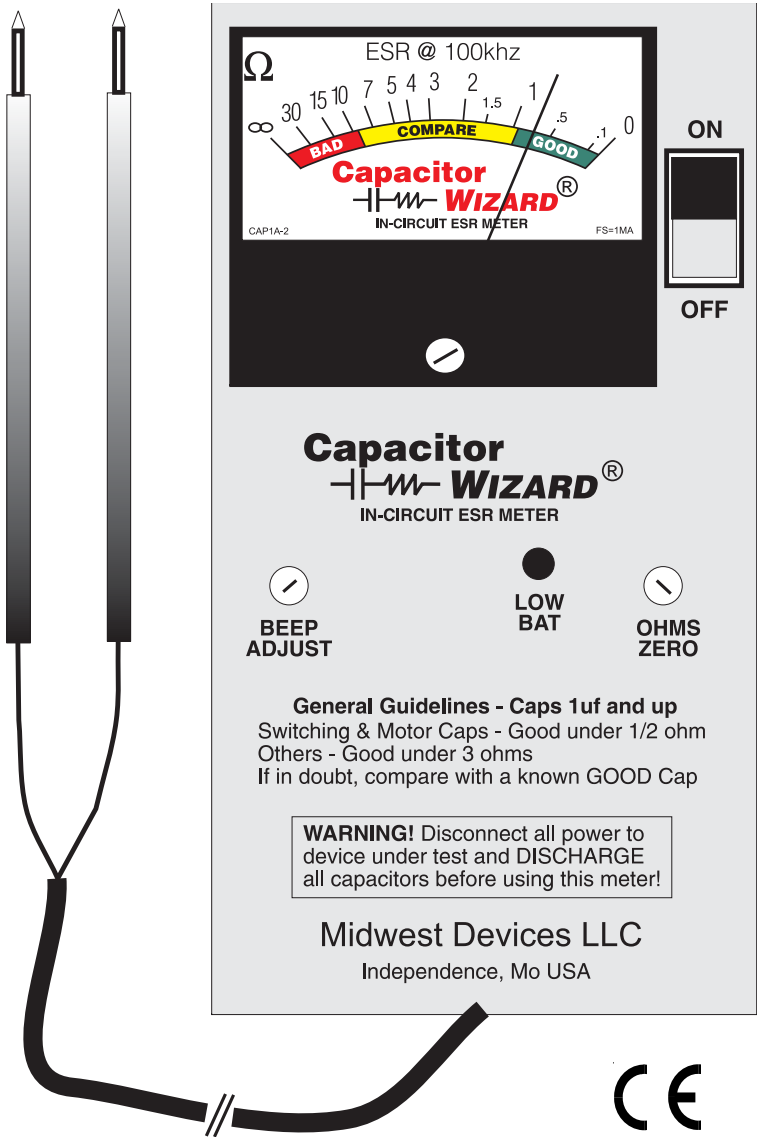
Limited Warranty

Midwest Devices LLC warrants this product to be free of defects in materials and workmanship for a period of one year from the date of purchase. If you find a defect MIDWEST DEVICES LLC will, at its option, replace or repair the product at no charge to you, provided you return it during the warranty period, transportation charges prepaid both ways to MIDWEST DEVICES LLC. The purchaser is responsible for shipping charges EACH WAY. This warranty does not apply if the product has been damaged by Acts of God, negligence, accident, abuse or misuse or misapplication, has been damaged because it has been improperly connected to other equipment, or has been modified or tampered with in any way. This warranty is limited to the replacement or repair of this product and not to damage to equipment of other manufacturers. Under no circumstance shall Midwest Devices LLC be liable for any loss, direct, indirect, accidental, special, or consequential damage arising out of or in connection with the use of this product. There is no other warranty expressed or implied. This warranty will be cancelled if the Capacitor Wizard® internal circuitry has be tampered with in any way. This warranty is not transferrable and applies only to the original purchaser. Warranty is valid only in the United States of America.

Operating Manual

Capacitor WIZARD®

In-Circuit Capacitor Analyzer



CE

WARNING!!

DISCONNECT all power to equipment under test and DISCHARGE the capacitors before using this device! Failure to do so may damage the Capacitor Wizard®, equipment under test, and ***could be hazardous to the operator***. Damage caused by attempts to use this device on powered up equipment or charged capacitors is NOT covered by the Warranty!

Description:

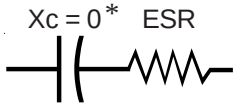
The Capacitor Wizard® is a highly sensitive, low impedance AC Ohm Meter designed specifically to find bad capacitors based upon measured ESR (Equivalent Series Resistance), 1uf and up, **in or out of circuit**. The meter probes are *nonpolar*. The output of the meter is a 100khz SINE WAVE. Output voltage is less than 15mv pp (5mv rms) and will not turn on any solid state devices in the circuit under test. An analog meter displays ESR plus BAD-COMPARE-GOOD. An audio beeper sounds when a capacitor is GOOD, eliminating the need to look at the meter.

The Capacitor Wizard® circuitry is designed to maximize its' ability to measure low ESR values. By measuring for ESR at a relatively high frequency and by using other proprietary design techniques, the Capacitor Wizard® can accurately measure ESR of capacitors 1 uf and up IN-CIRCUIT. Capacitors from 0.1 to 1uf can be tested, however you must refer to the chart on page 6 to interpret meter readings.

The Capacitor Wizard® Measures "Zc"

Standard Impedance Formula: $Zc = \sqrt{ESR^2 + Xc^2}$

PROOF: Zc = ESR



If $Xc = 1 / (6.28 * F * C) \cong 0^*$

Then:

$$Zc = \sqrt{ESR^2 + 0^2} = \sqrt{ESR^2} = ESR$$

* @100khz measuring caps 1uf and above Xc Approaches 0

General guidelines for expected ESR by Capacitor Type
If in doubt, compare meter reading to a known Good Cap

Capacitor Types and Expected ESR - 1uf & up

(the "<" sign means "less than",the ">" sign means "greater than")

Metalized Polypropylene Metalized Polyester Polyester (Mylar) Motor Start & Run Electrolytic Switching < 63v	Good Less than 1/2 ohm

Non-Switching Power Supply, High Power Audio

Electrolytic > 63v Electrolytic General Purpose	Good less than 3 ohm

Signal level Audio, Low Frequency Bypass & Coupling

Low Quality Electrolytics	These vary from 1 to 10 ohms.

Meter Reading Chart for ***GOOD IDEAL*** Caps Below 1uf
(An ideal Capacitor has 0Ω ESR)

.047	30 ohms
.1uf	15.9 ohms
.22uf	5 ohms
.33uf	2.2 ohms
.47uf	1 ohm
.56uf	.8 ohm
.68uf	< 1/2 ohm
.7uf	< 1/2 ohm
.8uf	< 1/2 ohm
.9uf	< 1/2 ohm

Example: The Capacitor Wizard® should read around 15.9 ohms for a good 0.1uf capacitor according to the chart.

About ESR

"Equivalent Series Resistance"

Why Check for ESR?

Standard capacitance meters require removing the part from the circuit. Worst yet, capacitance meters can ***mislead a technician.*** Capacitors frequently measure the proper capacitance on a standard capacitance meter yet have high ESR! When the Capacitor Wizard® reports the capacitor bad, it's bad! Who cares what the actual capacitance is? Replace it. It's bad. Since ESR is dependent upon the capacitor dielectric material and the construction techniques, even slight defects in a capacitors operation can be detected by measuring ESR. Most capacitor failure modes cause a large increase in ESR. With high ESR capacitors will not function as intended! If you don't check for ESR you may be in for a "tough dog" repair. High ESR is the first sign of capacitor failure!

What is ESR?

ESR (Equivalent Series Resistance) is the sum of all internal resistances of a capacitor measured in ohms. ESR is a DYNAMIC quantity and must be measured with an AC test signal. When there is no significant capacitive reactance, ESR is the ***AC RESISTANCE*** of a capacitor. ESR of a capacitor is affected by construction techniques, dielectric properties, frequency of operation and temperature. ***An IDEAL capacitor has ZERO ohms ESR.***

What are the effects of high ESR?

Undesirable! High ESR will cause complete circuit failure, overheating of capacitors, loading of the circuit, overstressing of other circuit components, changes in time constants, and other undesirable effects.

ESR and Temperature

ESR is sensitive to temperature. An unusual property of ESR is that, on electrolytics, ***ESR goes DOWN as temperature goes UP!!*** The inverse temp relationship can cause bad caps to suddenly start working after warm-up! So check caps when they are cold. You may see this effect for yourself by simply holding an electrolytic capacitor between your fingers and monitor the ESR with the Capacitor Wizard®!

What's good and bad ESR?

Capacitors of the same value in uf vary widely in ESR depending upon the type of material the capacitor is made of and how it is constructed. Bad open caps always measure near infinity and are simple to locate. Field tests have determined that modern capacitors measuring ESR of **10 ohms and over are almost always bad.** Open caps ALWAYS CHECK BAD. ESR of **less than one ohm is generally a GOOD cap.** Capacitors measuring in the COMPARE area of 1 to 10 ohms could be caps with higher voltage ratings, those used in circuits not requiring particularly low ESR such as audio preamps, or marginal low ESR parts. Modern solid state circuits such as switching power supplies **require low ESR capacitors!** With a little experience the user will quickly know the difference between a good cap and a bad cap.

Is ESR a new capacitor characteristic?

No. However in the past capacitor manufacturers have referred to **LOW ESR** in different ways: "high AC current carrying capability", "low ripple voltage", "high ripple current capabilities", "low dissipation factor", "high Q", "low power factor". Each of these quantities infer LOW ESR. Capacitor manufactures are beginning to publish **standardized ESR specs** in their product manuals.

Measuring Capacitors In-Circuit

Turn off all power to the device under test (D.U.T.)!!!! Properly DISCHARGE all capacitors to be tested!!! Capacitor discharging is very important as the input resistance of the Capacitor Wizard® is only 2.5 ohms. The Capacitor Wizard® appears as a *SHORT CIRCUIT to the D.U.T!* An optional protection device, CapSVR part #CW1B-SV, is available from our website: http://www.midwestdevices.com/parts.html.

Turn on the Capacitor Wizard® and short the probes together. Check that the meter reads ZERO ohms. If not, adjust the OHMS ZERO control. The BEEPER should beep when the probes are shorted. If not, go to the "Beeper Adjustment" section. Verify Capacitor Wizard® operation by measuring a low value resistor. Select a capacitor to test. Place a probe on either side of the cap, polarity is not important. Observe the meter reading. A **good capacitor** should measure **below 1 ohm**. A **bad cap** will measure **more than 10 ohms**. An open cap will measure near infinity and is very easy to spot.

Finding "MARGINAL" caps: The Capacitor Wizard® is a sensitive device with the ability to locate not only BAD caps but also marginal capacitors. These measure 1 to 10 ohms and need to be compared to a known good cap of the SAME TYPE, VALUE, AND VOLTAGE RATING until you become familiar with the Capacitor Wizard®. You will find that the marginal caps can cause all kinds of "Tough Dog" problems. They often test good on standard capacitance testers yet the high ESR causes them to fail.

Be aware of the circuit you are working on. A low quality general purpose cap in an audio circuit may measure marginal, or even high (maybe 7 ohms or more), and yet may be perfectly acceptable as a low power audio coupling cap! That same cap would be unacceptable in a switching application. With experience you will quickly know the difference between a good marginal cap and a bad one. When in doubt, compare it to a known good cap until you have gained experience.

What the Capacitor Wizard® may NOT FIND

Although the Capacitor Wizard® will find over 90% of the bad capacitors IN CIRCUIT, every piece of test equipment has its limitations. Capacitors are simple parts in theory but in the real world they are complex devices with many different properties and failure modes. Certain failures may require additional test equipment and removal of the capacitor. These are:

1) Dead shorted capacitors: The Capacitor Wizard® Measures ESR and, by definition, the best ESR is zero ohms. For this reason the Capacitor Wizard® cannot recognize dead shorted caps. Use a standard DC ohmmeter if you suspect a shorted cap.

2) A bad capacitor in PARALLEL with a good one: Parallel capacitors have parallel ESRs that follow ohms law for resistors in parallel. The total ESR will be lower than the lowest parallel capacitors' ESR! You must **disconnect one capacitor** if capacitors are paralleled. Paralleling capacitors is used to lower overall ESR. Be aware - Paralleling capacitors is sometimes done in switching power supplies and high end audio.

3) Capacitor out of capacitance tolerance: Sometimes capacitors, due to no particular failure, are just out of capacitance tolerance. Maybe due to poor capacitor design or maybe they were just barely in tolerance when new.... Use an inexpensive capacitance reading meter to find these.

Using the BEEPER

The BEEPER provides a quick audio method of identifying **GOOD** capacitors without looking at the meter. **If the Wizard beeps, the capacitor is good!** The beeper can be used to find intermittent capacitors and connections. A "raspy" sound indicates intermittent connection. Use the beeper to grade caps before installing them in a product. Set a GO / NO-GO threshold and anyone can grade caps!

Beeper Adjustment

You may adjust the "beeper good" threshold to suit the kind of capacitors you are testing. We consider most capacitors good under 1/2 ohm so we set the beeper threshold to 1/2 ohm. This is the factory adjustment. To change the beeper adjustment, hold the meter probes together and adjust the "ZERO OHMS" control to the desired beep point on the meter (such as 1 ohm). Adjust the "BEEP ADJUST" control until the Capacitor Wizard® just beeps. Re-Zero the meter.

Other Possible Uses

Find Shorted PC Traces.

Since the Capacitor Wizard® measures low values of A/C resistance, it can be used to locate shorted parts on a common power bus. Remove the caps first. Series and parallel INDUCTORS will appear as open circuits. I have used the Capacitor Wizard® to find solder bridges when testing the products we manufacture. This works best on small PC traces that have sufficient resistance to be within the AC ohms range of the Capacitor Wizard®

Find Shorted/Leaky Diodes & Transistors IN CIRCUIT

Because the Capacitor Wizard® Uses a 100khz test frequency, the Capacitor Wizard® ignores inductors over 50uh. It also will not turn on GOOD solid state junctions. For these reasons it may be used to **locate shorted or leaky diodes and transistors** attached to coils and transformers **IN CIRCUIT!!** Transistors containing damper diodes can also be tested for shorts/leakage IN CIRCUIT. Back to back diodes too! **Think about the possibilities!**

Measuring Small Resistors

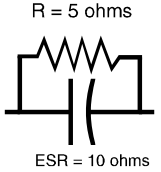
Low value noninductive resistors may be measured out of circuit. This is how the factory checks the calibration of each Wizard. Measure low value resistors to verify Capacitor Wizard® operation.

Measuring Small Inductors

The Capacitor Wizard® may be used to measure small inductors. Refer to the chart on the opposite page. This chart is only good for high "Q" inductors!! Low "Q" inductors will cause the actual measurement to be 30% or more in error, however comparisons to a known GOOD inductor IDENTICAL to the test inductor are valid and fairly sensitive. Compare the Capacitor Wizard® reading in ohms to the chart to obtain the approximate inductance. This measurement works only on small inductors with inductive reactance @100Khz within the ohms range of the Capacitor Wizard® as shown by the chart. These small inductors would be found mainly in RF tuning circuits.

Effects of parallel resistance

The Capacitor Wizard® is useful in circuit even if a capacitor is paralleled with low resistance. Consider the unlikely case of a bad open capacitor with a 5 ohm parallel resistor.. The Capacitor Wizard® will measure 5 ohms (the parallel resistor). That falls in the COMPARE area of the meter scale. Comparing to a known good would likely show that capacitor bad. Redefine BAD as greater that 1/2 ohm and the Wizard® works with even lower parallel resistance!



Example of a parallel 5 ohm resistor across a BAD switching capacitor
(A GOOD switching capacitor is defined as having less than 1/2 ohm ESR)

If the capacitor would open up the Wizard would measure 5 ohms - Bad!

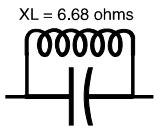
If the capacitor went up high in ESR, say 10 ohms, the Capacitor Wizard would measure about 3.3 ohms - Still Bad!

$$Rtotal = \frac{R \times ESR}{R + ESR} = 3.3 \text{ ohms}$$

Effects of parallel inductance

Inductors have inductive reactance. The Capacitor Wizard® will read inductive reactance within the 30 ohm range of its scale. At the 100Khz test frequency of the Capacitor Wizard® most inductors have many times more inductive reactance than the Capacitor Wizard® 30 ohm scale and can be ignored. The Capacitor Wizard® is useful down to parallel inductors of 10uh (that's a very small inductor). TV yoke windings, horizontal output transformer windings, switching power supply transformer windings, and motor windings are all much higher than 10uh and appear as an open circuit to the Capacitor Wizard® therefore they have no affect on the Capacitor Wizard® ESR meter reading!

F = 100,000 Hertz
L = 10uh (.000010 Henry)



Example of a parallel 10uh coil across a BAD switching capacitor
(A GOOD switching capacitor is defined as having less than 1/2 ohm ESR)

$XL = 6.28 \times F \times L = 0.628 \times 10 = 6.68$ ohms

If the capacitor would open up the Wizard would measure 6.68 ohms - Bad!

If the capacitor went up high in ESR, say 10 ohms, the Capacitor Wizard would measure about 5.5 ohms - Still Bad!

$$\text{AC resistance} = \frac{XL \times ESR}{\sqrt{XL^2 + ESR^2}} = 5.5 \text{ ohms}$$

The 10uh coil is shown for the worst case example only. It is very small compared to the magnitude of inductance you will actually find in TV's, Monitors, Switching Power Supplies and Motors. Inductances over 1000 uh with A/C resistance over 6,000 ohms are more likely.

Measuring Small Inductors

Compare the Capacitor Wizard® reading in ohms to the chart to obtain the approximate inductance.

Test Inductors: Toroid MPP
Material: Molypermalloy Hi Q
Manuf: Arnold Engineering
Part# A-291061-2
Windings: Sufficient # of turns to produce indicated ohms on Capacitor Wizard®

TEST EQUIPMENT
AC Ohms : Capacitor Wizard®
Inductance: Boonton 63H Inductance Bridge

0.1 ohm	=	0.3 uh
0.5 ohm	=	1.3 uh
1.0 ohm	=	2.5 uh
1.5 ohm	=	3.3 uh
2.0 ohm	=	4.2 uh
3.0 ohm	=	5.9 uh
4.0 ohm	=	7.6 uh
5.0 ohm	=	9.1 uh
7.0 ohm	=	13 uh
10.0 ohm	=	17 uh
15.0 ohm	=	25 uh
30.0 ohm	=	48 uh