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Frequency Dependence of Equivalent Series Resistance Measurement

With a little encouragement from his friends, the author finds a better way to test the equivalent series resistance of capacitors in or out of a circuit.

Doug is one of the experts behind the counter at Gateway Electronics in St Louis, MO.[1] Folks from a wide area seek his advice on repairing electronic stuff, so Doug has seen a lot of failed electrolytic capacitors in the past several years. (It seems that some Chinese manufacturers used inferior materials in the capacitors they manufactured.)

Doug had Mark Kreske build an equivalent series resistance (ESR) meter to check out suspect capacitors. Mark is a college student pursuing a degree in electronics. Mark and I are two of Doug's "groupies." Doug was troubled that Mark's meter identified some but not all bad capacitors. In particular, Doug had some known bad devices on a computer motherboard that checked okay with Mark's meter.

Doug set out to interest me in this problem and gave me some bad capacitors to evaluate. I measured the transmission of signals through the capacitor under test as a function of frequency with my DDS Sweep Measurement System and saw the behavior in Figure 1.[2] A good electrolytic capacitor of moderate value behaves like the short circuit baseline reference over most of the frequency range.

The results clearly show small differences between good and bad capacitors around 100 kHz, and a substantial difference at low audio frequencies. Strangely, all the ESR meter designs I find on the Internet operate in the neighborhood of 100 kHz.[3,4,5,6,7,8,9] This has to be wrong!

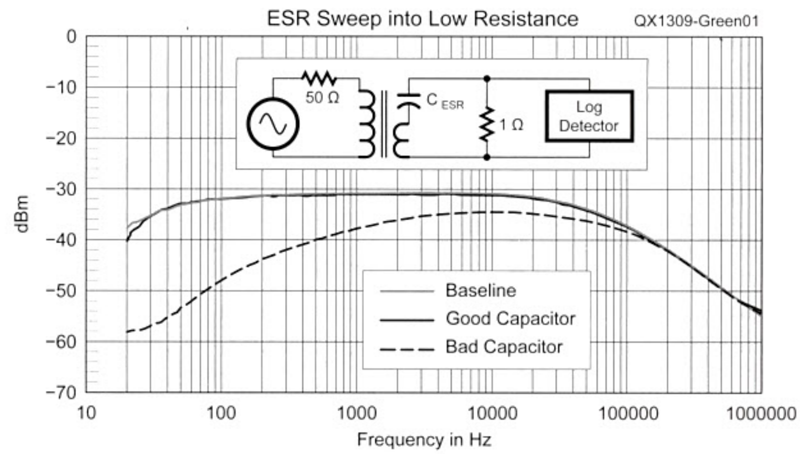

Figure 1 — Transmission through good and bad electrolytic capacitors versus frequency.

Mark used the schematic diagram shown in Figure 2 to build his ESR meter. This circuit came from a meter described at Note 3. I built the same meter, with some simplifications, and modified it to work at two frequencies to enable comparisons.

The first simplification is to use three AAA cells for power rather than a regulated 5 V supply.

The second simplification is to tie the five buffer outputs together and use a single 130 Ω resistor in place of five 680 Ω resistors.

The dual frequency modification involves changing R1 from 1 kΩ to 1 MΩ to lower the operating frequency below 100 Hz. Then I switch a 1 kΩ resistor in parallel with the 1 MΩ resistor to operate at the higher frequency.

I increased capacitors C2 and C3 from 0.01 μF to 10 μF and C6 from 0.1 μF to 1 μF in order to enable operation at the lower frequency. C5 (0.47 μF at 400 V) is difficult to increase. Instead, I omitted C5

[1]Notes appear on page 27.

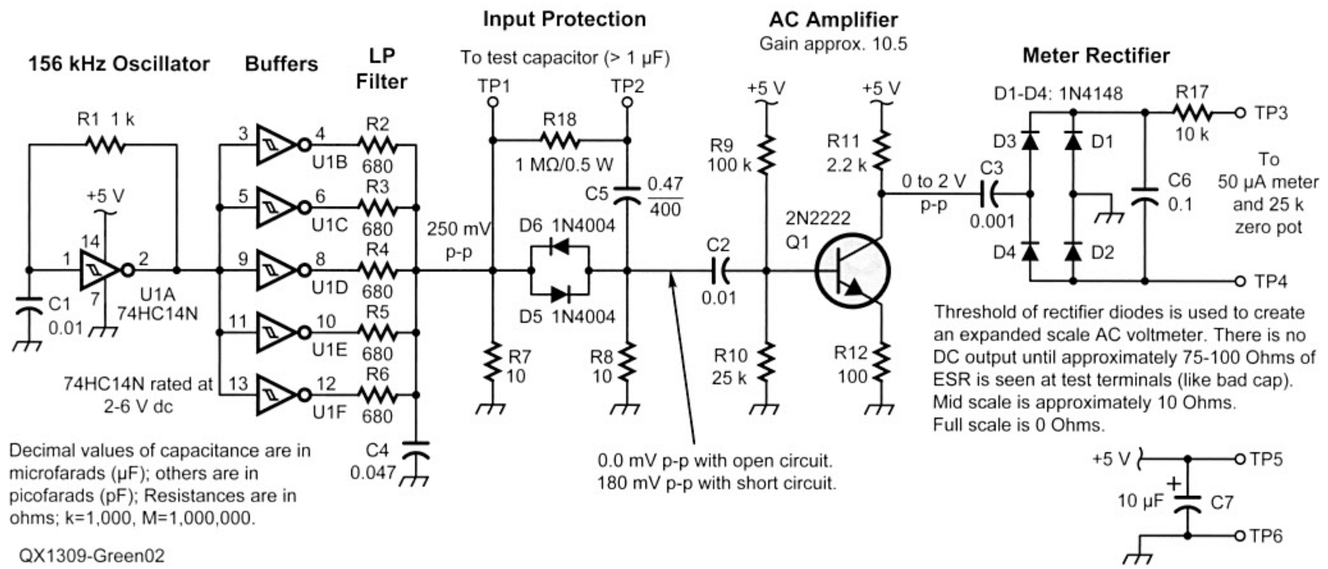

Figure 2 — ESR Meter schematic diagram from the Electronics DIY website, as listed in Note 3.

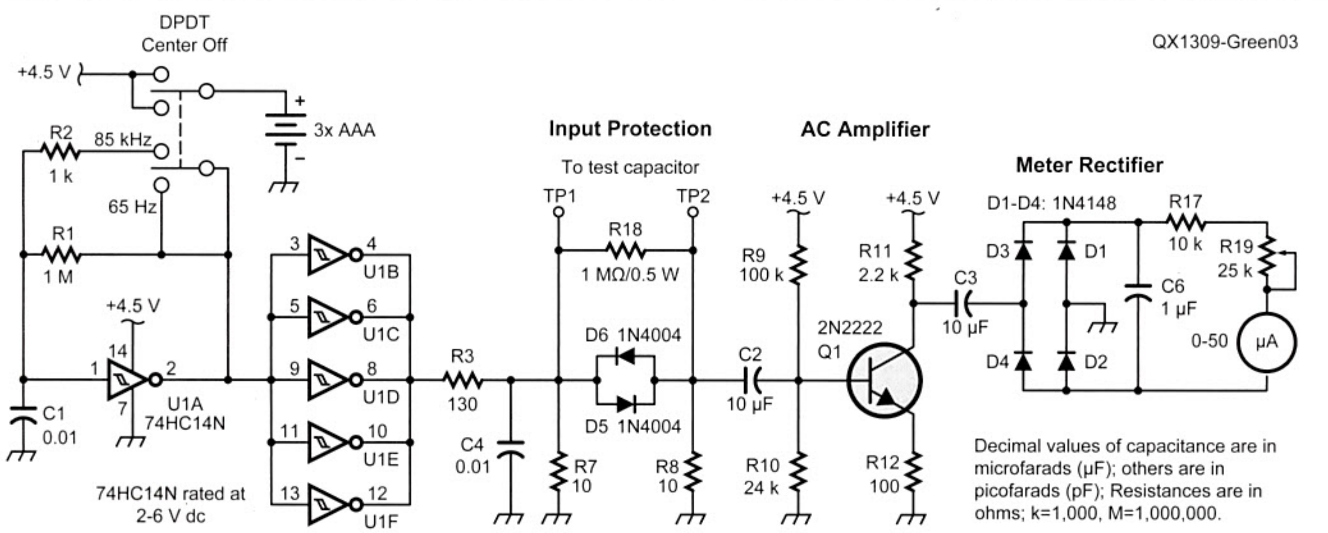

Figure 3 — ESR Meter with modifications for dual frequency operation.

by replacing it with a short circuit. The intent of C5 is to protect the circuitry from rapidly discharging a charged capacitor. I discharge my capacitors prior to testing.

Figure 3 shows my final circuit. I used a DPDT center-OFF switch to connect three AAA cells to provide the +4.5 V supply. One ON position selects the 1 MΩ timing resistor for 65 Hz operation. The other ON position shunts the 1 MΩ timing resistor with the 1 kΩ timing resistor for 85 kHz operation.

This circuit, in low frequency mode, correctly identified the known bad capacitors on Doug's motherboard. I suggest that ESR meter users modify their instruments in this manner to improve their ability to identify bad components.

Dr Sam Green, WØPCE, is a retired aerospace engineer. Sam lives in Saint Louis, Missouri. He holds degrees in Electronic Engineering from Northwestern University and the University of Illinois at Urbana. Sam specialized in free space optical and fiber optical data communications and photonics. He became KN9KEQ and K9KEQ in 1957, while a high school freshman in Skokie, Illinois, where he was a Skokie Six Meter Indian. Sam held a Technician class license for 36 years before finally upgrading to Amateur Extra Class in 1993. He is a member of ARRL, a member of the Boeing Employees Amateur Radio Society (BEARS), a member of the Saint

Louis QRP Society, and breakfasts with the Saint Louis Area Microwave Society. Sam is a Registered Professional Engineer in Missouri and a Life Senior Member of IEEE. Sam holds seventeen patents, with one more patent application pending.

Notes

[1]The Gateway Electronics web site is **www.gatewayelectronics.com**/.

[2]Sam Green, W0PCE, "A Full Automated DDS Sweep Generator Measurement System — Take 2," Sep/Oct 2012 *QEX*, pp 14-24.

[3]The ESR meter that we started with is described by Lawrence Glaister, VE7IT, on the Electronics_DIY website at: **electronics-diy.com/electronic_schematic.php?id=949**

[4]An ESR meter that was first described by Manfred Mornhinweg, XQ6FOD, is presented on the MZ Entertainment website at: **www.mzentertainment.com/studio_workshop_test_equipment_esr_meter.html**.

[5]Lee Davison describes a similar ESR meter at **mycorner.no-ip.org/misc/esr/esr_04.**

[6]For a description of a five transistor ESR meter, see: **www.eevblog.com/forum/projects/5-transistor-esr-meter-design/**.

[7]For information about an ESR meter kit see: **www.users.on.net/~endsodds/**.

[8]There is an ESR meter that uses a 555 timer IC described at: **koti.mbnet.fi/hsahko/elek/kv/esr/index.en.shtml**.

[9]For an ESR meter circuit that uses a resistor bridge design, go to: **kakopa.com/ESR_meter/**.