

ESR Measurement using Square Wave, Resistor and Oscilloscope

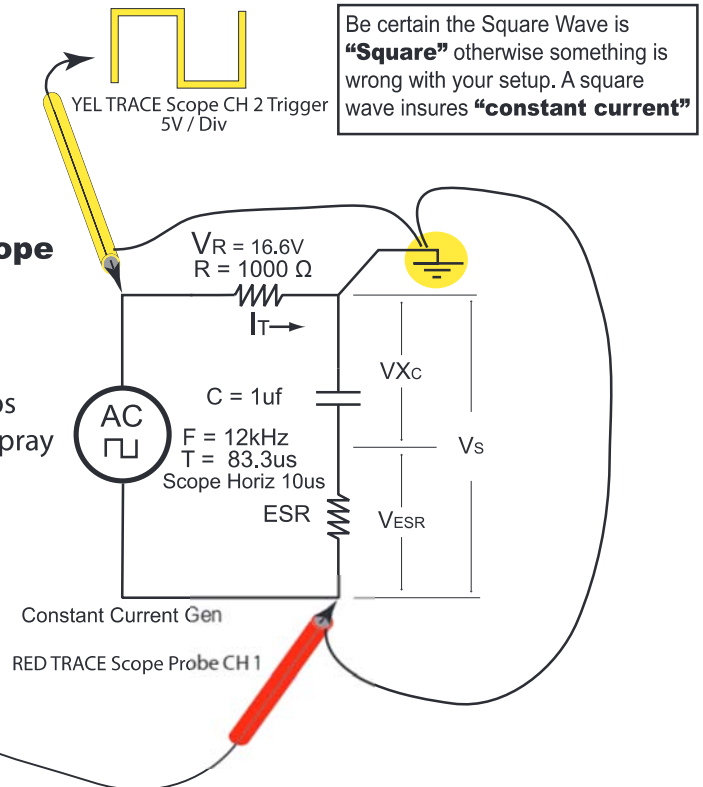
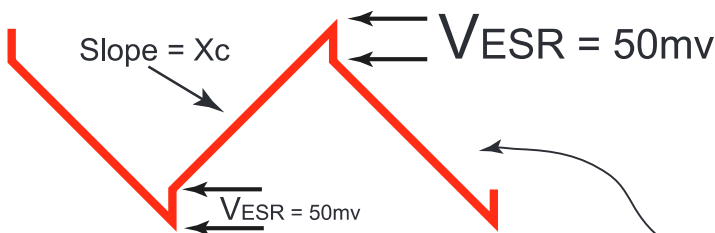
WARNING! I have isolated the safety grounds on the power plugs of both the oscilloscope and the waveform Gen. The safety grounds are tied to the BNC connectors on both the Waveform Gen and the Scope. In the circuit configuration below you must isolate the safety grounds or you will short out the waveform generator.

Units: Voltage "V_R", "V_{ESR}" in VOLTS, amperage "I_T" in AMPS, resistance "R", "ESR" in OHMS Ω

Scope Settings for: **1uf ESR** Waveform Gen: State 1
Horiz: 10us Output Square High Z
CH1: DC X1 50mv/div F = 12kHz
CH2: DC X1 5V/div Trigger VPPgen = 20.00vpp
R = 1000 Ω
Acquire Mode: 16
Acquire Length 1000

1) Measure ESR with Sq Wave Gen and Scope

- Demonstrate how to measure ESR with this setup
- Verify agreement with Capacitor Wizard®
- Demonstrate that ESR is not frequency dependent
- Show Fluke 87-V capacitance meter misses bad caps
- Demonstrate inverse temp coefficient with freeze spray



Adjust the scope horiz and vertical & waveform gen until a pattern such as above is observed.

Measure V_R. **V_R and I_T will remain constant throughout our tests.**

$$V_R = 16.6V$$

Calculate the value of I_T by dividing the measured value of V_R by R.

$$I_T = V_R / R = 16.6V / 1000\Omega = 0.0166A \quad I_T = 0.0166A$$

$$ESR = V_{ESR} / I_T$$

Calculate ESR by dividing the measured value of V_{ESR} by I_T. ESR = V_{ESR} / I_T.

$$V_{ESR} = 50mv = 0.050V \quad 1uf \ 50v: \ ESR = V_{ESR} / I_T = 0.050V / 0.0166A = 3.01\Omega \quad ESR = 3.01\Omega$$

Test other capacitors. Notice "I_T" remains the same

$$100uf \ 35v: \ ESR = 0.0064V / 0.0166A = 0.39\Omega$$

$$220uf \ 35v: \ ESR = 0.0033V / 0.0166A = 0.20\Omega$$

$$1500uf \ 6.3v: \ ESR = 0.0352V / 0.0166A = 2.12\Omega$$

$$1000uf \ 16v: \ ESR = 0.0296V / 0.0166A = 1.80\Omega$$

Bad Capacitors. These are high uF and low voltage. They should be less than 0.5 ohm.

Now check these capacitor's with the Capacitor Wizard® and verify agreement!

DOUGS TECH NOTES

By Doug Jones, Managing Member
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Square Wave Analysis of ESR

Manufacturer of...

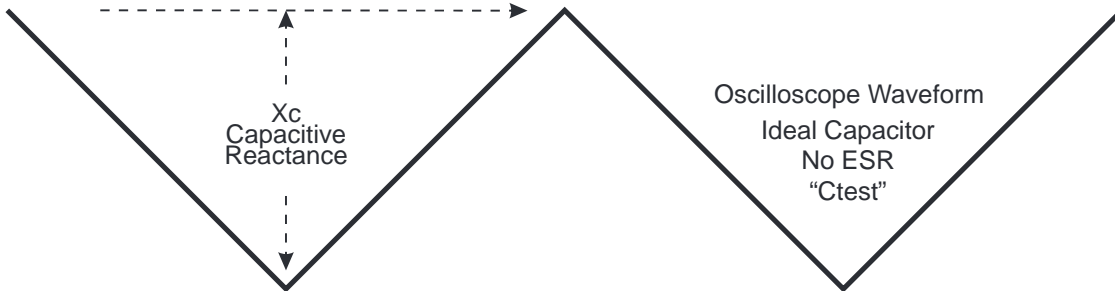
Capacitor WIZARD[®]
IN-CIRCUIT ESR METER

0 Deg 180 Deg 0 Deg 180 Deg 0 Deg

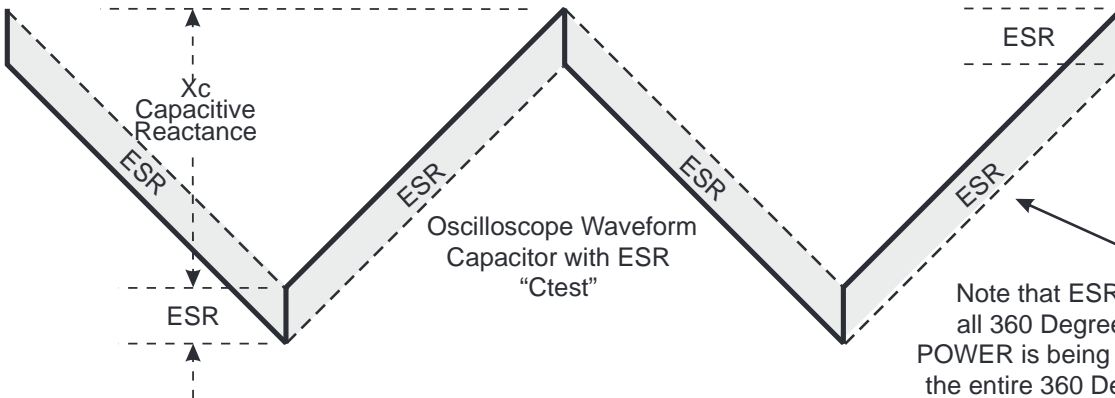
“A”
Current
Waveform
Measure
across “Rs”



“B”
Voltage
Waveform
IDEAL
CAPACITOR
No ESR



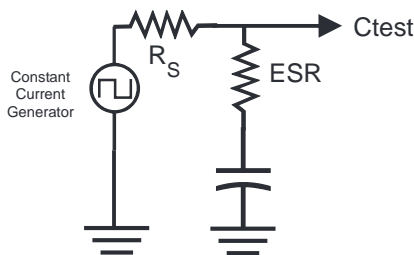
“C”
Voltage
Waveform
With ESR



“D”



Waveform after X_c is “Zero’d Out” by raising the frequency. **Only ESR is Left!!**
Now we can calculate ESR directly: $ESR = \text{Peak to Peak AC Voltage (E Ctest)} / \text{Constant Current (R}_S)$



$$ESR = E(Ctest) / I(R_S), (E = I \times R)$$