ESR Meter Circuit Description/theory of Operation

ESR METER INSTRUCTIONS & SERVICE INFORMATION

INTRODUCTION

The ESR Meter is basically an AC Ohmmeter with special scales and protective circuitry. It provides a continuous reading of series resistance in electrolytic capacitors. It operates at 100 kHz to keep the capacitive reactance factor near zero. The remaining series resistance is due to the electrolyte between the capacitor plates and indicates the state of dryness. Capacitor termination problems also show up plainly due to the continuous ohmic reading.

INSTRUCTIONS FOR ESR METER

Start by clipping the probes together and setting the zero adjust knob to a zero reading. Check every electrolytic you see. Your judgment of ESR increases with experience. You'll notice that capacitors usually check very good or very bad. Marginal capacitors accelerate their own failure. Variable ESR when wiggling leads: Capacitor is unreliable. Replace. (Be sure test clips are tight and direct to capacitor leads; don't use chassis ground.)

Over 50 Ohms: It should be replaced. Even if it works today, it will probably fail within a year. You're doing yourself a favor by replacing it now and maybe saving yourself trouble later.

50-20 Ohms: OK for 1 to 50 MFD in medium or high impedance circuits like signal coupling or timing circuits. For capacitors over 50 MFD, we have established a general limit, which is based on manufacturer's data, circuit theory, and experience:

C x R = 1000
(MFD) x (OHMS) = (MAXIMUM)

Examples:
100 MFD: 10 Ohms Max.
1000 MFD: 1-Ohm Max.
10,000 MFD: 0.1-Ohm Max.

Capacitors smaller than 1.0 MFD can be checked by comparison with an out-of-circuit capacitor of equal type & capacitance. This will show approximate capacitance, opens, shorts (usually zero ohms), and intermittent terminations, Tt1s always been a problem trying to attach a copper or steel lead to aluminum foil. With marginal capacitors, try paralleling or substituting with a known good one and re-check equipment performance. Circuit requirements for ESR vary somewhat.

The ESR Meter can monitor ESR in live circuits up to 600 volts, provided the circuit ripple doesn't change the reading from what you had with the circuit off. The ESR Meter will ignore about 10 volts p-p at 120 Hz; less at higher frequencies. I don't recommend testing live circuits because of the shock hazard and because we haven't found it necessary. Change batteries when the Zero Adjust setting changes drastically. Battery changing instructions are inside the ESR Meter. Keep solvents and sprays away from the plastic meter cover.

ADDITIONAL INSTRUCTIONS

1. A shorted electrolytic will check good on the ESR Meter, but is rare. Less than 1% of all field-failures are shorted. If you suspect a shorted capacitor check it with a conventional ohmmeter out of circuit.
2. Non-Polarized electrolytic check the same as Polarized.
3. Directly paralleled electrolytic must be separated for ESR testing.

CIRCUIT DESCRIPTION

The typical method used for measuring ESR is to supply the capacitor with a known AC current (Icap) at some frequency where the capacitive reactance of the capacitor is very low so that the ESR dominates. By measuring the resulting AC voltage developed across the capacitor's terminals (Vcap) the ESR can be determined with Ohm's law:

$$ESR = Vcap/Icap$$

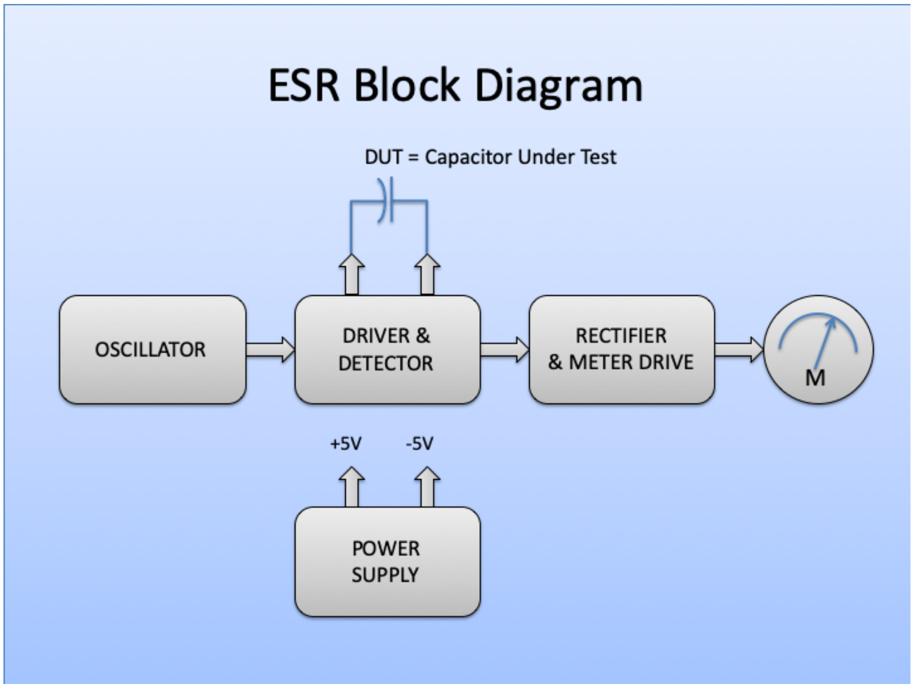


Figure 1. Block Diagram

Figure 1 is a block diagram of the ESR meter. Going from left to right there is an oscillator that supplies AC voltage to be applied to the capacitor. Next the AC signal is fed into an impedance converter and detector. The detected signal is then rectified and buffered so that it can drive the meter on the right of the diagram. Since the ESR meter is to be battery operated the power supply circuit supplies split rails for the operational amplifiers that will be used in the ESR meter. The oscillator is operated at 100 kHz. The driver used to reduce the impedance of the AC signal could be anything from a transistor current boost, transformer, or paralleled logic gates. The detector was usually back-to-back diodes. The detected AC signal is then rectified, amplified and fed into a DC meter.

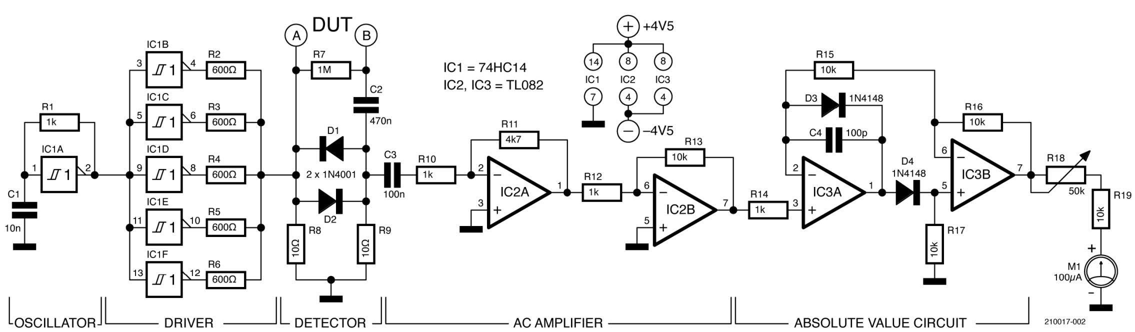


Figure 2. ESR Schematic

Figure 2 shows the schematic of the capacitor testing circuit.

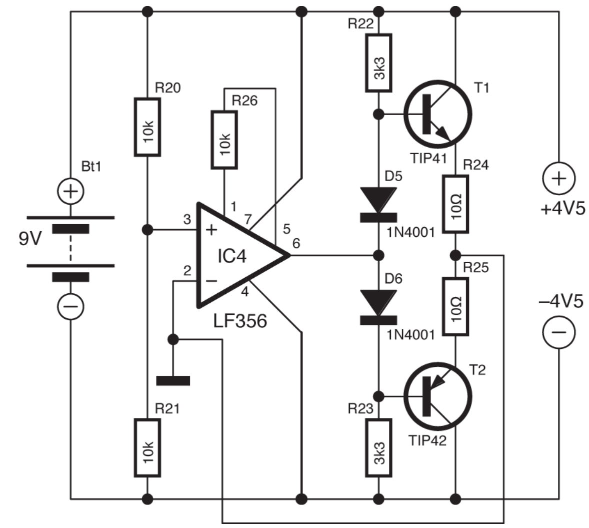


Figure 3. Power Supply

Power Supply

The ESR meter operates on a single 9-volt battery. Figure 3 shows the schematic of the circuit used to derive the split power supply rails needed for the AC amplifier IC2 and absolute value circuit IC3. The plus, minus and ground voltages needed for the operational amplifiers are generated using an op-amp voltage follower with current boost. The ground reference is set by the voltage divider R20 and R21. The current boost circuit is comprised of diodes D5, D6 and complimentary transistors T1 and T2. Biasing of the transistors is set by R22 and D5 for T1, and R23 with D6 for T2. Linearity of the circuit is improved by including the boost section inside the feedback loop of the unity gain voltage follower. This is accomplished tying the junction of R24 and R25 with the inverting input of op-amp IC4.

Oscillator

R1 and C1 in combination with Schmitt trigger IC1A create a 100 kHz relaxation oscillator. The frequency of the oscillator is determined by the time constants of the resistor and capacitor and the hysteresis of the Schmitt trigger. The equation for the relaxation oscillator is presented here.

$$f = \frac{1}{RC\ln\left(\frac{V_{High} - V_{T-}}{V_{High} - V_{T+}} \times \frac{V_{T+}}{V_{T-}}\right)}$$

Equation 1. The general equation for frequency.

Using Chart 1 from the 74HC14 datasheet the threshold voltages can be determined based on a 4.5-volt power supply.

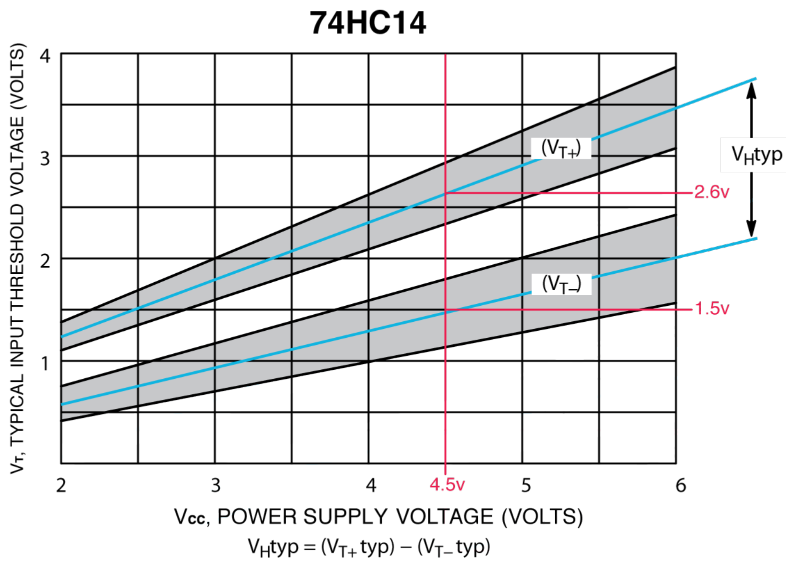


Chart 1. Typical Input Threshold, **VT+**, **VT–** versus Power Supply Voltage

Based on Chart 1 the specific threshold values for IC1 (74HC14) can be substituted along with the values for R1 and C1 into Equation 2.

$$f = \frac{1}{1k\Omega \times .01\mu f \ln\left(\frac{4.5v - 1.5v}{4.5v - 2.6v} \times \frac{2.6v}{1.5v}\right)} \approx 100kHz$$

Equation 2. The values used for a 74HC14.

Driver

The remaining gates in the 74HC14 are used to lower the impedance and buffer the output of the oscillator, which is connected to inverters IC1B through IC1F. 680-ohm build out resistors are added to the output pins of the remaining five inverters. Resistors R2-R6 are tied together to feed DC de-coupling capacitor C3 that then connects to the detector.

Detector

A blocking capacitor, C2 blocks out or stops any steady-state DC current that might result from any charge stored on the electrolytic capacitor being tested. C2 is a non-electrolytic and has its value selected so that it capacitive reactance Xc and its ESR are extremely small at the normal operating frequency of the ESR meter and can be, for all practical purposes, zeroed out or considered negligible at the 100 kHz operating frequency of the meter. A pair of back-to-back diodes, D1 and D2 is connected in parallel across the input of the AC amplifier. These diodes protect the input of the AC amplifier against current surges that may result when the electrolytic capacitor is initially placed under test. Diodes D1 and D2 also clip the top and bottom of the 100 kHz AC to one silicon junction drop, or .7 volts. This allows capacitors to be tested in circuit because any other silicon junctions in the piece of equipment under test will not be forward biased by this relatively low AC signal.

AC Amplifier

The AC amplifier is further protected from DC by series capacitor C3. The AC amplifier is comprised of two op-amps, IC2A and IC2B. The voltage gain of IC2A is approximately 5 and the voltage gain of IC2B is approximately 10 for a total voltage gain of 50. The output of the AC amplifier couples directly into the absolute value circuit through R14 to pin 3, the non-inverting input of op-amp IC3A.

Absolute Value Circuit

For a positive input signal on the non-inverting input of op-amp IC3A D3 becomes reverse biased. The output of IC3A drives the non-inverting input of IC3B through forward biased diode D2. The feedback to the inverting inputs of both IC3A and IC3B is from the output of IC3B through resistors R15 and R16. Since no current flows through resistors R15 or R16, in this condition, VOUT is precisely equal to the input of IC3A.

When the input voltage to the absolute value amplifier becomes negative, D4 becomes reverse biased. IC3A drives R15 through forward biased diode D3 to a voltage equal to the input of IC3A. IC3B, R15, and R16 form a simple unity gain-inverting amplifier. R15 and R16 are matched to provide accurate gain = –1V/V to match the +1V/V gain for a positive input signal. Compensation capacitor C1 ensures the circuit is stable with IC3B in the feedback loop.

Component Listing

Values and rating:

Designator	Value	
C1	.01 uf	20 Volts
C2	.47 uf	600 Volts
C3	.1 uf	20 Volts
C4	100 pf	20 Volts
C5	100 uf	25 Volts
C6	100 uf	25 Volts
> D1, D2, D5, D6	1N4001	Diode
> D3, D4	1N914	Diode
M1	100 uA	Analog Meter
Q1	TIP41	NPN Transistor
Q2	TIP42	PNP Transistor
R1	1K	1/4 watt
> R2 - R6	680 Ohm	1/4 watt
R7	1M	1/4 watt
> R8 - R25	10 Ohm	1/4 watt
> R10 - R14	1k	1/4 watt
R11	4.7k	1/4 watt
> R13 - R21	10k	1/4 watt
> R22, R23	3.6k	1/4 watt
R26	10k	1/4 watt
RV18	50k	1/4 watt
U1	74HC14	X6 Schmitt Inverter
> U2, U3	TL082	Dual Op-amp
U4	LF356	Op-amp

Table 1. List of Components

Component Locater

Component Locations on printed circuit board:

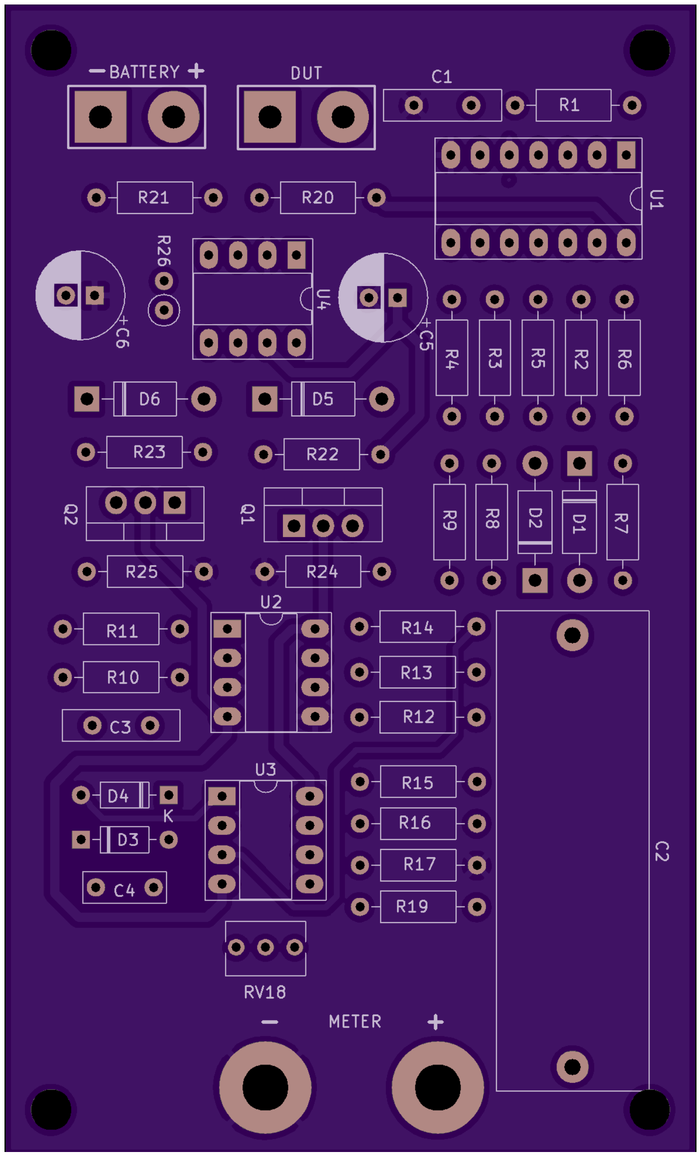
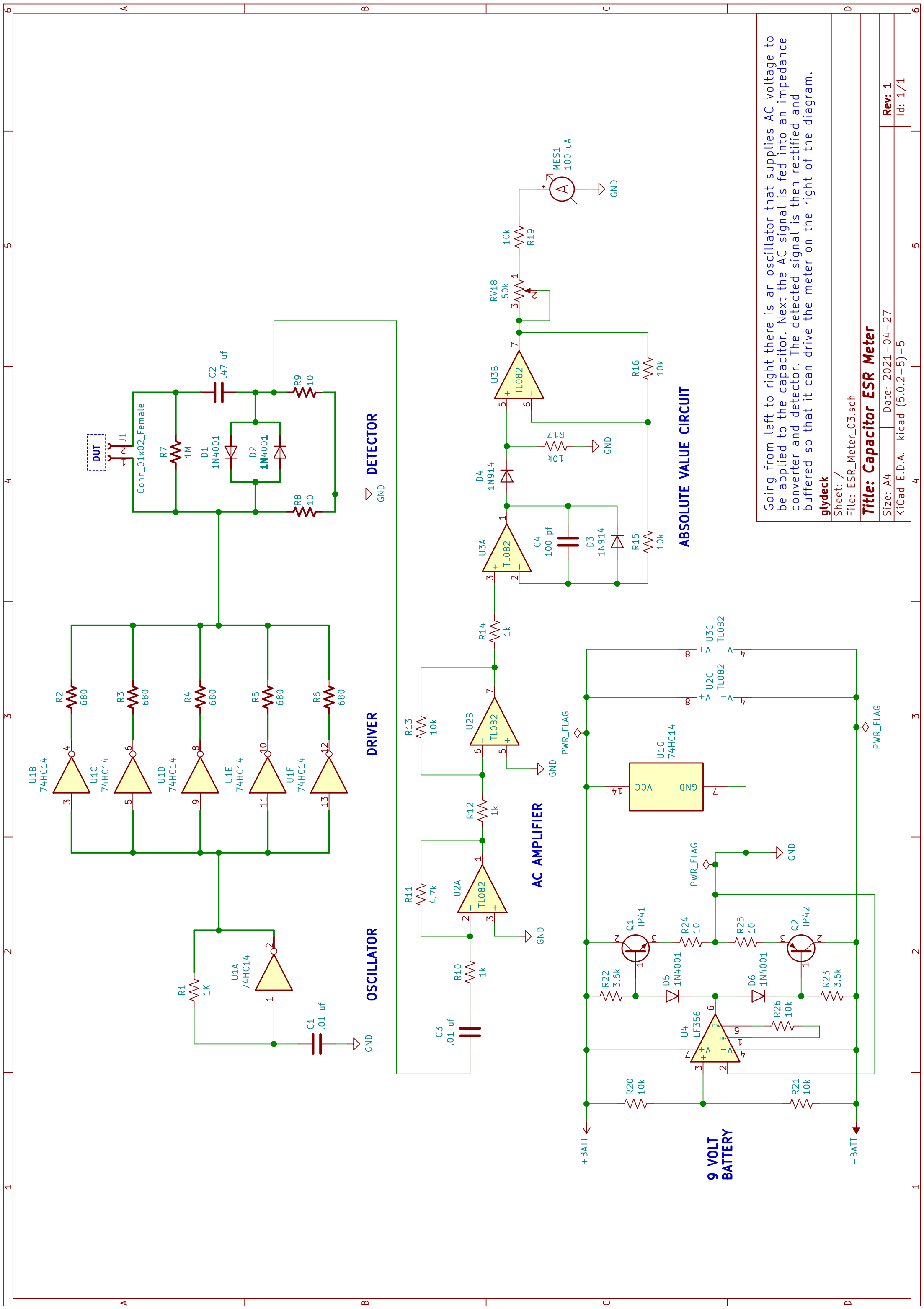


Figure 4. PCB Component Locater


OSCILLATOR
DRIVER
DETECTOR
AC AMPLIFIER
ABSOLUTE VALUE CIRCUIT
9 VOLT BATTERY
DUT
Going from left to right there is an oscillator that supplies AC voltage to be applied to the capacitor. Next the AC signal is fed into an impedance converter and detector. The detected signal is then rectified and buffered so that it can drive the meter on the right of the diagram.
glydeck
Sheet: /
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Title: Capacitor ESR Meter
Size: A4
Date: 2021-04-27
KiCad E.D.A. kicad (5.0.2-5)-5
Rev: 1
Id: 1/1