Capacitor ESR Meter

A typical capacitor checker measures the capacity (usually in micro farads) of the test capacitor. Some advanced units also test for leakage current. Most of these testers require that the capacitor be removed from the circuit. Unless the capacitor has totally failed, they will not detect a high ESR value. In a typical circuit, there may be 10's or 100's of capacitors. Having to remove each one for testing is very tedious and there is a great risk of damaging circuit boards. This tester uses a low voltage (250mv) high frequency (150khz) A/C current to read the ESR of a capacitor in the circuit. The in circuit testing is possible because of the low voltage used for obtaining the measurement. The voltage is low enough that solid state devices in the surrounding circuitry are not activated and do not affect the low resistance reading we are attempting to obtain. A lot of capacitor checkers will be damaged if you happen to test a charged capacitor. This circuit is A/C coupled and will withstand up to 400vdc of charge on a capacitor (but watch your fingers!). The ESR checker will not detect shorted capacitors as they will read with a very low ESR value. If you are trouble shooting a circuit, you will have to use several instruments including your nose, voltmeter and oscilloscope to locate all the possible failure modes. My experience has found that the ESR meter catches about 95% of capacitor problems and potential problems.

What is ESR?

"ESR" stands for equivalent series resistance. ESR is one of the characteristics that defines the performance of an electrolytic capacitor. Low ESR is highly desirable in a capacitor as any ripple current through the capacitor causes the capacitor to heat up due to the resistive loses. This heating accelerates the demise of the capacitor by drying out the electrolyte at an ever increasing rate. Over the lifetime of a capacitor, it is not uncommon for the ESR to increase by a factor of 10 to 30 times or even go open circuit. Typical lifetime ratings for electrolytics are 2000-15000 hours and are very dependent on ambient operating temperature. As the ESR increases, the filtering operation of the capacitor becomes impaired and eventually the circuit fails to operate correctly.

Features

Tests electrolytic capacitors > 1uf in circuit.
Caps may be tested in circuit or by bridging them across the terminal posts or using test leads.
Polarity insensitive testing.
Tolerates charged capacitors up to 400vdc.
Low battery draw (approx 25ma) resulting in about 20 hours of battery time when using 4 cheap AA nicads.
Easy to read analog meter.
Measures ESR range from 0-75ohms with an expanded scale A/C ohmmeter.

Circuit Description

See the schematic for component designations. The circuit starts with a 150khz oscillator using one gate of a 74hc14. The rest of the gates are used as buffers to increase the current drive to the low pass filter. The single pole low pass filter is necessary because the square wave signal contains a lot of energy in high frequency odd order harmonics. The output of the filter is applied across a 10 ohm load resistor that provides the low impedance drive signal to the test capacitor. Diodes D5 and D6 protect the circuit from discharge spikes if you happen to test a charged capacitor. R18 is used to discharge C5 so that you don't blow up anything if you alternately test charged high and low voltage caps. C5 isolates the test circuit from DC voltages up to 400 volts.

Be careful if you are testing high voltage capacitors... the safest way to work is to make sure the test capacitors are discharged before testing them. Be aware that high voltage capacitors can hold a lethal charge for several days depending on the circuit design. I learned this first hand in high school electronics class. Students (not to be named!) used to charge the caps and put them back on the shelf for the next unsuspecting victim to pick up.

The rest of the circuit is a very straight forward transistor amplifier with a gain of about 10.5. This amplifies the A/C signal passed through the test capacitor up to several volts in amplitude. The signal is then coupled to a full wave bridge

rectifier that has the meter as its load. The threshold voltage of the bridge rectifier is used to an advantage and provides the expanded scale function of the ohm meter. The amplified voltage from the test capacitor must be great enough to overcome 2 diode drops before the meter will start to respond. This sets the high resistance threshold for the meter at somewhere between 75-100 ohms. The meter is zeroed by shorting the test leads together and adjusting the pot in the meter circuit for a full scale (0 ohms)reading on the meter. Proper operation of the circuit can be verified by checking several values of resistors with the meter. Shorted leads should indicate full scale, a 1 ohm resistor should read about 90% of full scale, a 10 ohm resistor should read about 40% of full scale and a 47 ohm resistor should barely move the needle to about 10% of FSD. The absolute readings will vary with temperature and battery voltage, but the idea is that most ESR values should be much less than 10 ohms which means good caps test at very close to full scale and bad caps test at little or no deflection.

The board below shows my second prototype. The top 2 wires run to the front panel banana test jacks, the middle 2 wires are the incoming switched 5 volts from the 4 AA nicads, and the bottom 2 wires run to the series combination of the zero adjust pot and the meter on the front panel.

How to use ESR Meter

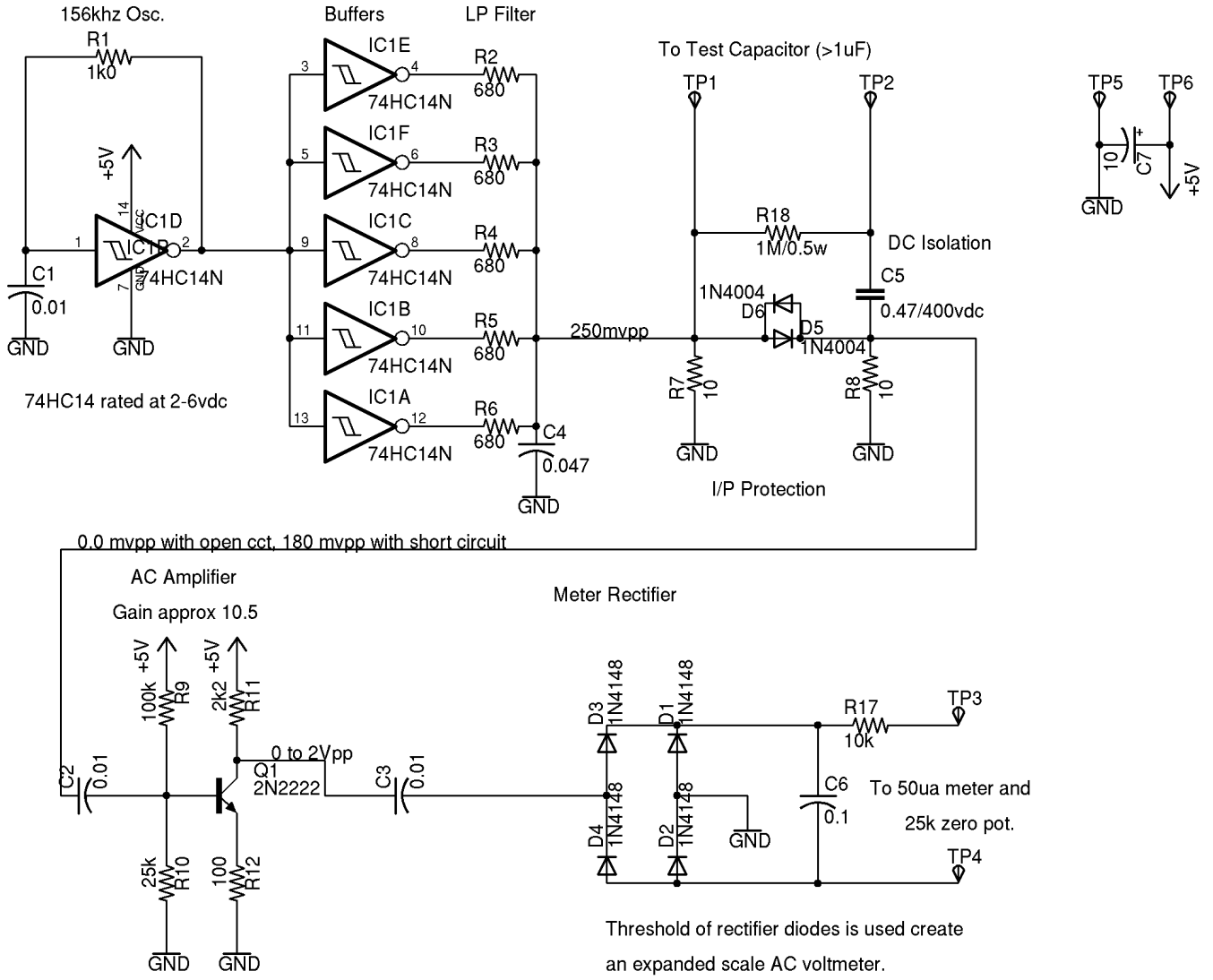
1. Separate the test leads of the ESR meter so that the probes are not touching. Turn the meter on. If the meter has more than one mode, ensure that is set to ESR mode. The meter may perform an automatic calibration routine when powered on. If so, wait until it indicates it is ready to use. This may be indicated by an LED or an audible tone.

2. If the capacitor to be measured is in-circuit, ensure that the circuit is not energized. Unplug the electronic equipment the capacitor is installed in, if possible.

3. Discharge the capacitor before testing if the ESR meter does not do this automatically. Choose a high-wattage resistor with a resistance of between 5 and 50 times the rated voltage of the capacitor. Connect a test lead to each lead of the resistor. Carefully touch the other ends of the test leads to the leads of the capacitor and hold them there for a few seconds. Use a voltmeter to confirm that the capacitor is not charged. The voltmeter should show a value of zero.

4. Touch the ESR meter test probes to the leads of the capacitor. Read the ESR of the capacitor from the meter. It may be displayed as a deflection on an analog scale, a level on an LED bar scale or a digital readout. Some ESR meters also provide an audible tone indicating the range of the ESR.

5. Determine if the ESR is acceptable by comparing the measured ESR value with the guidelines provided with the meter.



Threshold of rectifier diodes is used create
an expanded scale AC voltmeter.
There is no DC output until approx 75-100 ohms
of ESR is seen at test terminals (like bad cap).
Mid scale is approx 10ohms. Full scale is 0 ohms.

This circuit functions by applying a small 150khz AC voltage to the electrolytic capacitor being tested. The AC resistance of the cap is measured by an expanded scale A/C ohm meter circuit.
Caps can be tested live in circuit (not recommended).
The maximum AC voltage applied across the test cap is 250mv pp.
This will not turn on any solid state devices.
Caps tend to measure either full scale (good),
or no deflection (esr > 75 ohms... bad).

Cap	Good ESR
0.1	10
1.0	1
10	0.1
100	0.01
470	0.002
1000	0.001
4700	0.0002

Polarity of test leads does not matter.
The input will survive 400vdc (C5 rating).
Meter Powered by 4 Nicads

Capacitor Checker - Measures Equivalent Series Resistance (ESR)

TITLE: esr-meter

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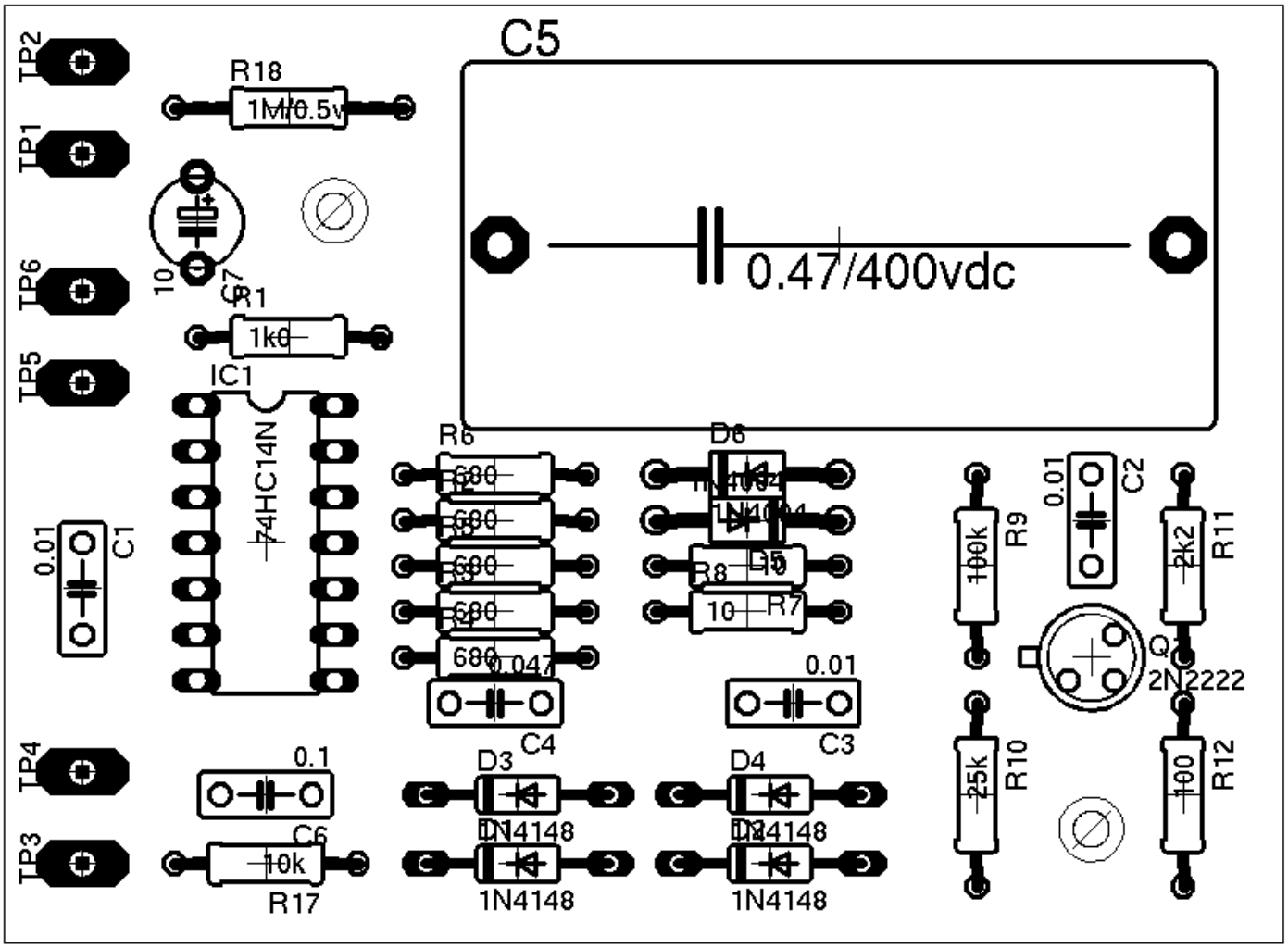
Date: 3/07/2005 21:52:08 Sheet: 1/1


C5
0.47/400vdc
TP2
TP1
TP6
TP5
TP4
TP3
R18
1M/0.5v
10
C7
R1
1k0
IC1
74HC14N
0.01
C1
R6
680
680
680
680
680
0.047
C4
D6
R8
10
R7
0.01
C3
0.1
C6
10k
R17
D3
D4
1N4148
1N4148
1N4148
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0.01
C2
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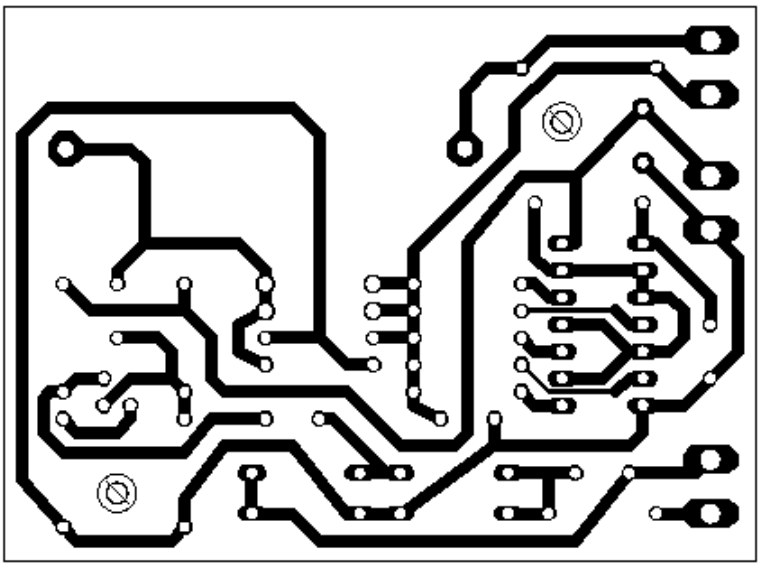
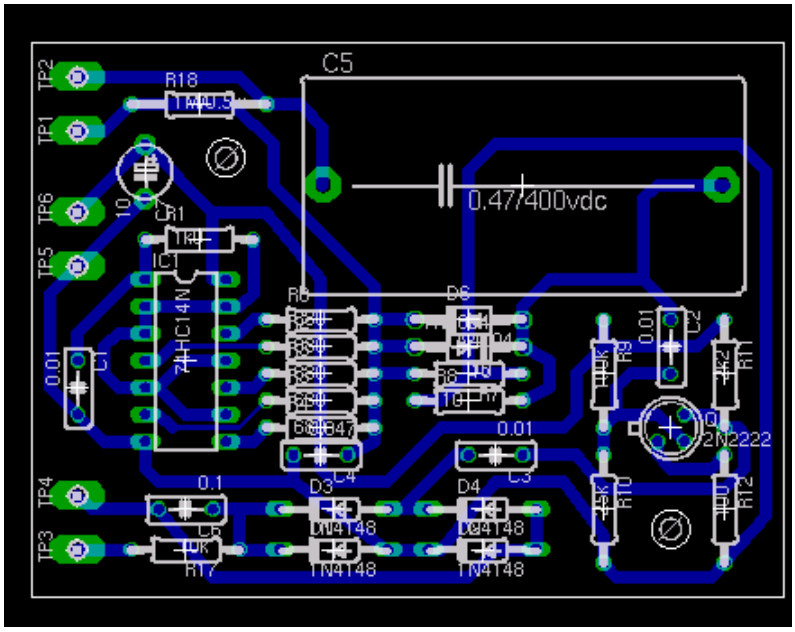
R9
2k2
R11
Q
2N2222
25k
R10
100
R12




C5
0.47/400vdc
R18
TP2
TP1
TP6
TP5
TP4
TP3
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IC1
74HC14N
C1
0.01
R5
R6
R7
R8
D3
D4
C4
C3
0.1
C2
R9
R10
R11
R12
R17
Q1
2N2222
1N4148