Terminal-configuration Technique Used to Measure Component

I. Forward

For alternating current (AC) component measurement meter (low-frequency LCR meter, F≤ 2MHz), in order to accurately measure the device under test (DUT), advanced measurement principle should be applied, such as I-V conversion, phase detection, ADC, advanced compensation technology, accurate calculation method, etc. But besides these, it's very important to select which terminal-configuration technique and apply the technique correctly, which affects measurement's veracity a lot. This article tries to give guide about how to achieve correct measurement through terminal-configuration technique by describing involved terminal-configuration technologies.

Because of LCR meters' different model, terminal-configuration techniques that are possibly applied differ. This article concludes five terminal-configuration techniques in the order from being simple to difficult, two-terminal (2T), three-terminal (3T), four-terminal (4T), five-terminal (5T), and four-terminal pair (4TP), with their characteristics, error source, and impedance range detailedly described.

II. Two-terminal (2T) Configuration

Figure 1 shows typical 2-terminal configuration. OSC is signal source, Rin is signal source resistance, V is high-resistance input voltmeter, and A is low-resistance input ammeter.

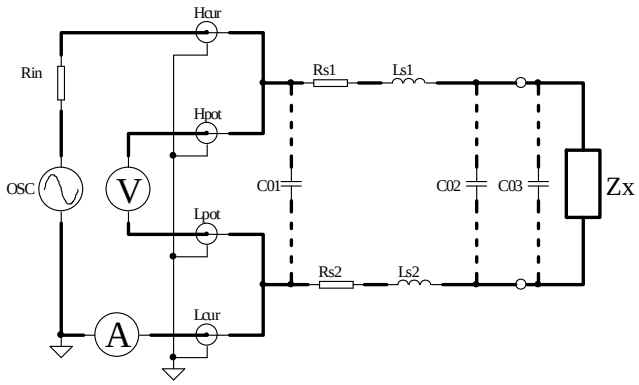


Figure 1 Two-terminal configuration

Hcur, Hpot, Lpot, Lcur: four UNKNOWN terminals

Hcur: High current

Hpot: High potential

Lpot: Low potential

Lcur: Low current

C01, C01: stray capacitance between two test cables

C03: stray capacitance on DUT (Zx)

Rs1, Rs2: contact resistance between test lead and DUT

Ls1, Ls2: inductance of test leads

Two-terminal configuration is the simplest way, but contains many error sources, because lead inductance, lead resistance, and stray capacitance between two leads have been added to measurement result. C01, C01, C03, Rs1, Rs2, Ls1, and Ls2 respectively have effect on measurement result to cause error. Generally, this terminal-connection method is not applied on

LCR meter, except few cases, such as portable LCR meter with very low accuracy (Tonghui TH2821 Portable LCR Meter applies five-terminal configuration).

And its typical impedance measurement range is limited to 100Ω to 10kΩ (without doing compensation).

III Three-terminal (3T) Configuration

Three-terminal configuration differs with two-terminal configuration only in shielded coaxial cable instead to serve as test cable. Shielded part is connected to guard terminal, such as BNC interface's outer conductor, and the shielded conductor is considered as one terminal.

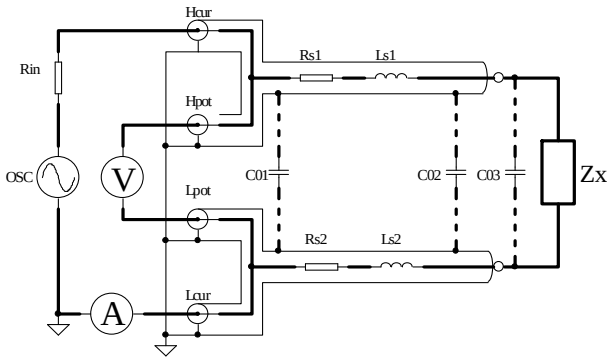


Figure 2 Three-terminal configuration

From Figure 2, we can see that stray capacitance C01, C02 are connected to outer conductor (shield), which doesn't affect test cable and reduce error of measuring high-impedance component. It will improve measurement accuracy in the measurement range of higher-impedance, but can't for lower-impedance because of lead inductance and lead resistance. C03 still has capacitance, and open correction could be performed to eliminate the stray capacitance. The typical impedance range will be extended to above10MΩ.

At the time of measuring component with high impedance and small capacitance, three-terminal configuration is applied to reduce conductor configuration's complexity, even not to affect measurement result.

IV. Four-terminal (4T) Configuration

As shown in Figure 3, four-terminal configuration has individual voltage test cable. Because voltmeter V is of high-impedance input, Hpot and Lpot directly measure voltage on DUT Zx, avoiding Rs1, Rs4, Ls1, Ls4's effect on measurement. Besides, because of high-impedance input of V, Rs2, Rs3, Ls2, Ls3 with low-impedance don't affect voltage measurement.

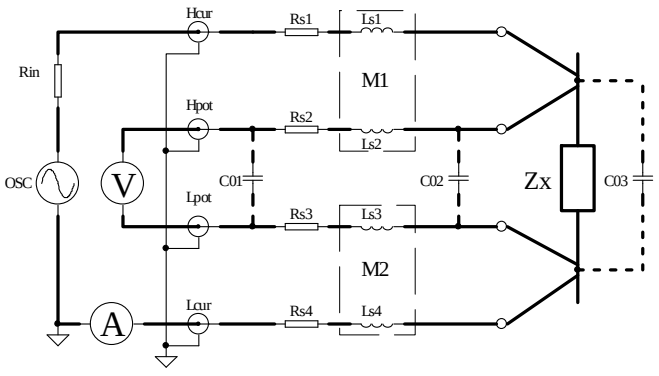


Figure 3 Four-terminal configuration

Stray capacitance C01, C02, and C03 still have effect, and mutual inductance M1and M2 between cables affect as well.

Four-terminal configuration can reduce the effects of lead inductance and resistance. Accuracy for the lower impedance measurement range is improved typically down to 1Ω. When the DUT's impedance is less than 1Ω, a larger signal current flows through the current path and mutual (M1, M2) coupling to the voltage sensing cable will cause an error.

V. Five-terminal (5T) Configuration

Five-terminal configuration is a common measurement configuration method of LCR meters, which has good performance and easy connection method. It is a combination of 3T and 4T configurations, equipped with 4 coaxial cables and all of the outer conductors are connected to guard terminal. This configuration has wide measurement range from 1Ω to 10MΩ, but the mutual coupling problem still remains. Therefore, five-terminal configuration eliminates effect of lead resistance and inductance, and lead stray capacitance.

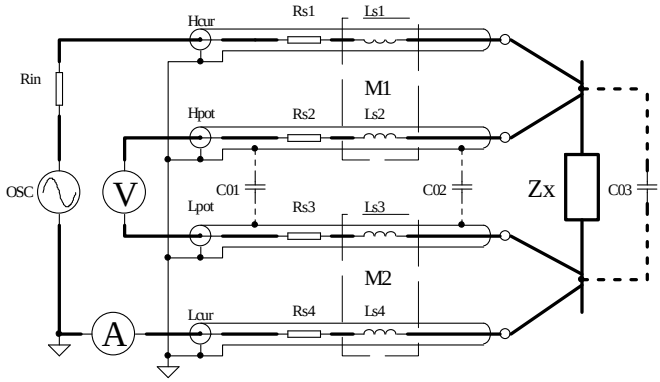


Figure 4 Five-terminal configuration

Five-terminal configuration has good balance in complexity of terminal-connection and effect of eliminating error. So it's a very effective terminal-connection technique of LCR measurement instruments. All Tonghui products apply five-terminal terminal-connection technique except TH2828 series.

VI. Four-terminal Pair Configuration

Problems of errors between test terminals have been solved in the above terminal-connection methods, but problem of electromagnetic coupling of mutual inductance between test cables still remains.

Four-terminal pair configuration solves the mutual coupling problem because it uses coaxial cable to isolate the voltage sensing cables from the signal current path. Since the return current flows through the outer conductor of the coaxial cable, the magnetic flux generated by the inner conductor is cancelled by that of the outer conductor (shield). The measurement range realizable for this configuration can be improved to below 1Ω. The impedance measurement range realizable for this configuration depends on the measurement

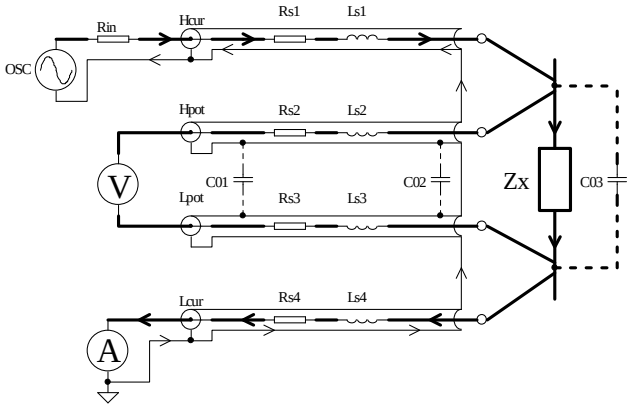
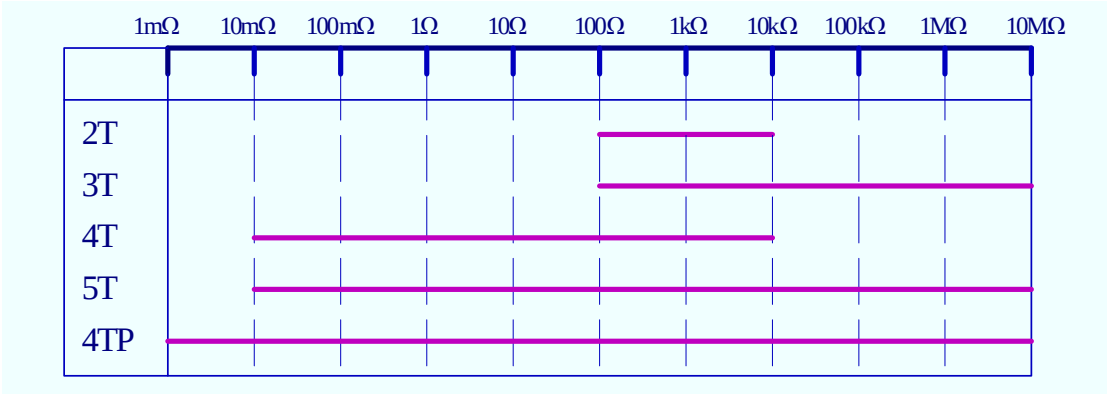


Figure 5 Four-terminal pair configuration

instrument and on how well the 4TP configuration is strictly adhered to up to the connection point of the DUT. If the cables are not connected properly, measurement range will be limited, or in some cases, measurement cannot be made at all. Tonghui TH2828/TH2828A/TH2828S applies this 4TP configuration.

VII. Impedance Ranges for Different Terminal-connection Configurations



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