Electronic Transformer Parameter Measurement Basics

Foreword

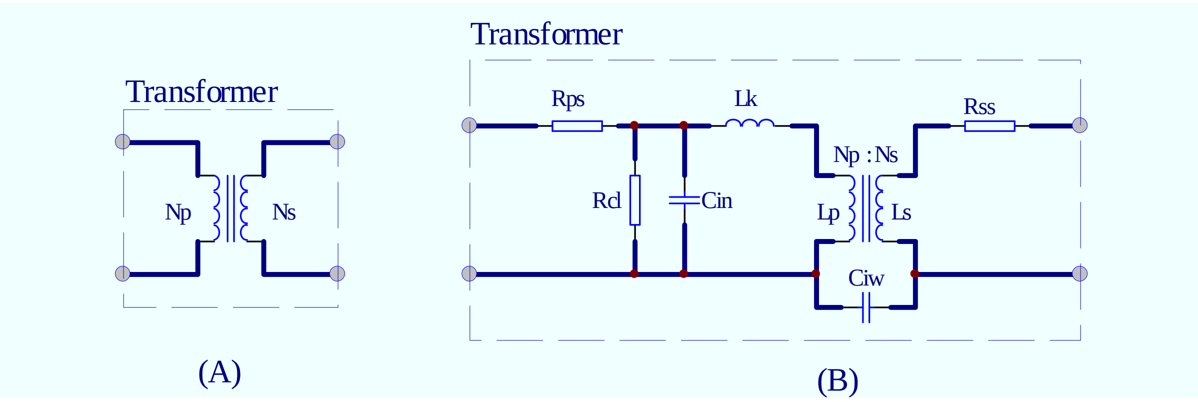
With the rapid development of electronic technology, more and more electronic products are required to reduce volume and improve efficiency. And it’s the most convenient way to improve efficiency of electronic circuit. Ferrite cores are used in an increasing proportion of transformer designs, therefore, transformer manufacturers must meet a need for smaller transformers designed to operate at higher frequencies, which introduces additional demands on both manufacturing and testing methods.

The issues discussed in this article are widely applied to many high-frequency transformer fields, such as switched power supplies, lighting ballasts, inverter driver, audio equipment, telecommunication equipment, etc. Today’s need for the proven performance of all components within a product has resulted in a demand for each and every transformer to be more thoroughly tested than traditionally expected.

This article discusses complete parameter measurement method used to describe ferrite transformer.

Electronic Transformer Parameter Contents:

Figure 1 (A) shows the simplest double-winding transformer, including quite a complex parameter contents. And Figure 1 (B) shows equivalent circuit composed of real transformer’s



parameter components.

Figure 1 Transformer parameter contents

From Figure 1 (B), it can be seen that even the simplest transformer includes a combination of resistive and reactive components. And among them,

Rps: lead resistance (copper resistance) of primary winding, existing in primary winding in series way

Rss: lead resistance (copper resistance) of secondary winding, existing in secondary winding in parallel way

Rcl: magnetic core's dissipation and insulation resistance of transformer framework and eduction lead, existing in primary winding in parallel mode

Lk: leakage inductance,

Ciw: stray capacitance existing between primary and secondary windings

Cin: stray capacitance existing at both ends of the coil

Ls: inductance composed by flux coupled from primary winding to secondary one

Lp: secondary inductance

Np: turns ratio of primary winding

Ns: turns ratio of secondary winding

Performance and quality of transformer are related to material and manufacturing technics, such as framework, circling means, material of magnetic core, jointing material, etc.

In order to ensure transformer is made of right materials through right techinics, it's necessary to take complete measurement for its parameters, to prove the materials and technics meet the requirements of the specification.

In theory, transformer is a final product of inductor; therefore, transformer measurement basically applies the same technology as inductor measurement. Key parameters of transformer and rough measurement will be described as follows.

Parameter Measurement

Pin Short:

Measurement objective: to ensure that the transformer is correctly seated in its fixture and that winding termination integrity is good. Either pin of the transformer can be measured.

Measurement item: DCR

Measurement range: 10Ω --100MΩ

By selecting this test first, the operator can be alerted if any connections are poor prior to executing the main tests, saving time and avoiding incorrect transformer error reports in batch statistics.

Rps, Rss：

Measurement objective: to ensure that the gauge of copper being used for each winding is correct.

Measurement item: DCR

Measurement range: 1mΩ--100MΩ

All windings are tested individually ensuring that there are no windings with an insufficient gauge of copper to carry the required current.

Lp, Ls:

Measurement objective: to ensure that the correct material has been used and that the number of turns is correct.

Measurement item: Ls

Measurement range: 10nH—100kH

Signal level: 5mV—2V @20Hz—300kHz,

DC bias: 0—100mA/0—1A

Different core materials and sizes exhibit different permeability and therefore a different value of inductance for a particular number of turns, $L \propto \mu_e N^2$. With the correct

ACR:

Measurement objective: to ensure that correct core material has been used, winding turns and the gauge of copper is correct.

Measurement item: Rs

Measurement range: 10μH—100MΩ

Signal level: 5mV—2V @20Hz—300kHz,

ACR reflects copper resistance Rs

Q: quality factor

Measurement objective: to ensure that core material and its assembly is correct.

Measurement item: Q

Measurement range: 0.0001—10000

Signal level: 5mV—2V @20Hz—300kHz

Quality factor represents the efficiency of an inductor as the ratio of energy stored to energy wasted and is derived from the equation $Q = L/R$. Accurately speaking, because of the exist of winding stray capacitance, $Q = L/R\sqrt{LC}$. It can be seen that the higher Q values are obtained when the inductive component is large relative to the resistive and capacitive components.

θ: Angle of impedance

Measurement objective: to ensure that the core material, wire resistance, number of turns and inter-winding capacitance combine to meet design specifications.

Measurement item: angle of impedance

Measurement range: -180--+180 º DEG

-3.14159--+3.14159 RAD

Signal level: 5mV—2V @20Hz—300kHz

For transformers in applications that operate over a wide frequency range, e.g. audio transformers, the designer or the production department may have to measure the phase angle between the real impedance (resistance R) and imaginary impedance (inductive or capacitive jX).

The sum of R and jX is commonly referred to as Z (total impedance). As the applied frequency is increased on an inductor the impedance increases and the impedance phase angel decreases up to the point of self-resonance, at this point the impedance phase angel is zero (also the highest impedance value).

Lk: Leakage inductance

Measurement objective: to ensure that windings are positioned correctly on the bobbin and that any air gap included in the core design is the correct size.

Measurement item: Ls

Measurement range: 10nH—100kH

Signal level: 5mV—2V @20Hz—300kHz，

Leakage inductance is the inductive component attributable to magnetic flux that does not link primary to secondary windings. Designs may require a specific value of leakage inductance for the correct operation of the circuit into which the transformer will be fitted or it may be necessary to keep the value very low. Measurement of leakage inductance requires the application of a short circuit to secondary windings and this can often present problems in a production environment.

Ciw: Inter-winding capacitance

Measurement objective: to ensure that the insulation thickness between windings is correct.

Measurement range: 100fFnH—10F

Signal level: 5mV—2V @20Hz—300kHz

Capacitance occurs in inductors and transformers due to the physical proximity of electrostatic coupling between wires within a winding. Capacitance also exists between separate windings from primary to secondary or secondary-to-secondary.

TR: Turns ratio

Measurement objective: to ensure that the number of turns on each winding and the winding polarity meet specification.

Measurement item: TR

Measurement range: 100 – 100:1

Signal level: 5mV—2V @20Hz—300kHz

Turns ratio is measured to establish that the number of turns on primary and secondary windings is correct and therefore the required secondary voltages are achieved when the transformer is in use. It is important to remember that the various transformer losses shown in

Figure 1 will result in a voltage ratio that does not correspond exactly with the ratio of physical turns present on the windings.

Turns ratio can be calculated through different measurement ways, including voltage ratio and inductance ratio which overcomes errors attributable to core loss and leakage inductance.

Phase: Wire direction

Measurement objective: to ensure that each wire on turns is in correct direction, that is,

Measurement item: turns ratio

Measurement range: +/-

Signal level: 1V @20Hz—300kHz

Turns ratio is measured to ensure that wires on primary and secondary turns are in correct direction to make phase of secondary output voltage meet requirement.

SUGE: High voltage surge testing (not available for TH2818X, TH2882 series instrument is needed to perform measurement)

Measurement objective: to ensure that the insulation material around the copper wire (usually lacquer) has not been damaged during manufacture introducing the risk of an inter-winding short circuit, and insulation intensity of insulation layer meets specification.

Measurement size: area, area difference, etc.

Impulse signal level: 500V—5000V

It easily causes problem of insulation damage to use very thin lead to make transformer with many turns. And it's difficult to avoid damaging insulation materials in production process; what's more, it's possible that insulation material hasn't been short completely. Damage to the insulation material during production is very difficult to detect as there may not be a total short circuit and the voltage applied during turns testing will not be very sufficient to bridge this partial short. However, during operation within the finished product, the transformer is exposed to much higher voltages which can cause a corona arc at the point of damage or the heating effect of normal use may cause a short circuit after a short period of time.

By connecting a charged capacitor to a transformer winding, the winding is exposed to an impulse voltage and by measuring the area under the decaying oscillation, it's possible to establish if a breakdown between turns of the winding has occurred.

By computing the volt-second product under the curve, the instrument provides a numeric quantity by which to establish good or bad components. This gives the benefit of shorted turns detection using an impulse voltage technique, while avoiding the potential errors inherent in user interpretation of complex waveforms.

Please refer to Impulse Measurement Technology of Winding Component about high voltage surge testing.

IR: Insulation resistance (not available for TH2818X series)

Measurement objective: to ensure that the isolation between windings meets the required specification.

HV AC: High voltage AC safety testing (not available for TH2818X series)

Measurement objective: to ensure that the windings are positioned correctly with the correct materials to provide the required level of safety isolation.

All transformers that provide isolation from an AC power system must be tested to confirm their ability to withstand safety-testing voltages without breakdown.

Conclusion

In order to completely ensure that all materials and production processes within a transformer are correct, transformer measurement system must guarantee that each and every transformer tested is known to fully meet the required specification. Such through testing here is too costly, too difficult and too time consuming. Tonghui TH2818 series transformer measurement system provides a cost effective, easy to use and fast solution.

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