5.3 Transformer measurement

A transformer is one end-product of an inductor so, the measurement techniques are the same as those used for inductor measurement. Figure 5-18 shows a schematic with the key measurement parameters of a transformer. This section describes how to measure these parameters, including L, C, R, and M.

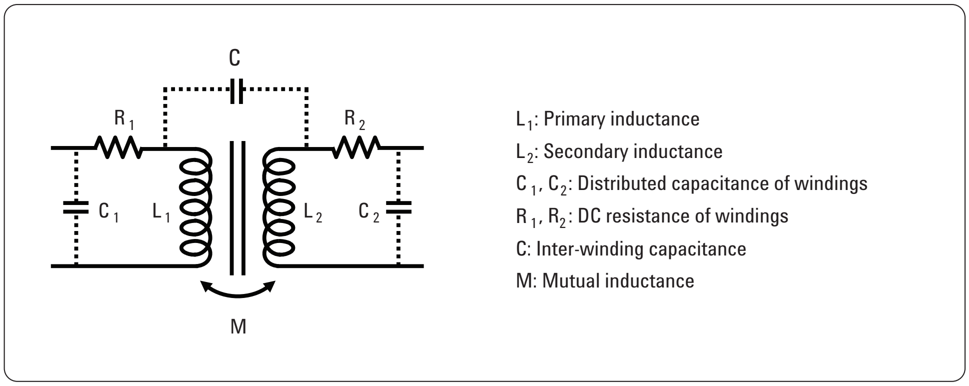

Figure 5-18. Transformer parameters

5.3.1 Primary inductance (L1) and secondary inductance (L2)

L1 and L2 can be measured directly by connecting the instrument as shown in Figure 5-19. All other windings should be left open. Note that the inductance measurement result includes the effects of capacitance. If the equivalent circuit analysis function of the Agilent's impedance analyzer is used, the individual values for inductance, resistance, and capacitance can be obtained.

Leakage inductance is a self-inductance due to imperfect coupling of the transformer windings and resultant creation of leakage flux. Obtain leakage inductance by shorting the secondary with the lowest possible impedance and measuring the inductance of the primary as shown in Figure 5-20.

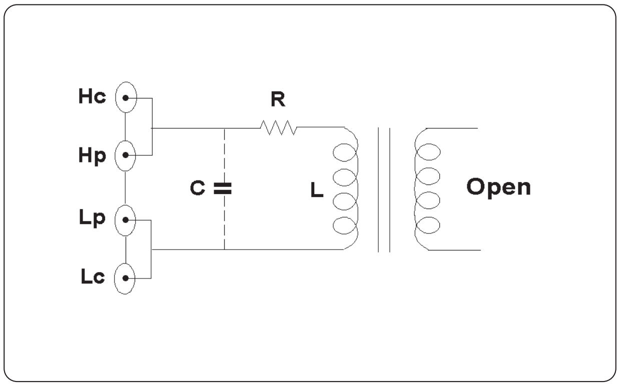

Figure 5-19. Primary inductance measurement

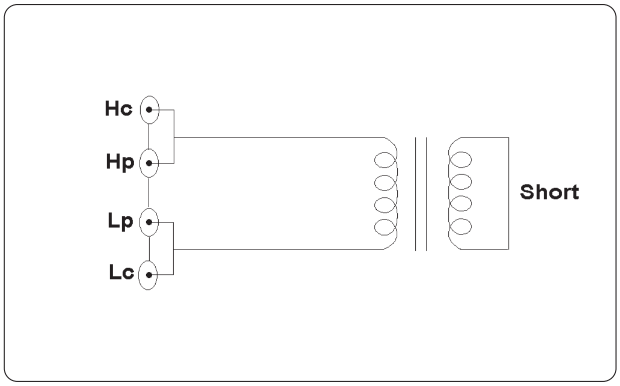

Figure 5-20. Leakage inductance measurement

5.3.2 Inter-winding capacitance (C)

The inter-winding capacitance between the primary and the secondary is measured by connecting one side of each winding to the instrument as shown in Figure 5-21.

5.3.3 Mutual inductance (M)

Mutual inductance (M) can be obtained by using either of two measurement methods:

(1) The mutual inductance can be derived from the measured inductance in the series aiding and the series opposing configurations (see Figure 5-22 (a).) Since the combined inductance (La) in the series aiding connection is La = $L_1 + L_2 + 2M$ and that Lo in the series opposing connection is Lo = $L_1 + L_2 - 2M$, the mutual inductance is calculated as M = (La – Lo)/4.

(2) By connecting the transformer windings as shown in Figure 5-22 (b), the mutual inductance value is directly obtained from inductance measurement. When test current (I) flows through the primary winding, the secondary voltage is given by V = jωM x I. Therefore, the mutual inductance can be calculated from the ratio between the secondary voltage (V) and the primary current (I.) However, the applicable frequency range of both measurement techniques is limited by the type and the parameter values of transformer being measured. These methods assume that the stray capacitance effect, including the distributed capacitance of windings, inter-winding capacitance, and test lead capacitance, is sufficiently small. To minimize the cable capacitance effect for the method shown in Figure 5-22 (b), the Hp test lead length should be made as short as possible. It is recommend to use both techniques and to cross-check the results.

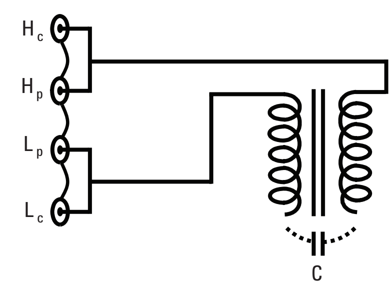

Figure 5-21. Inter-winding capacitance measurement

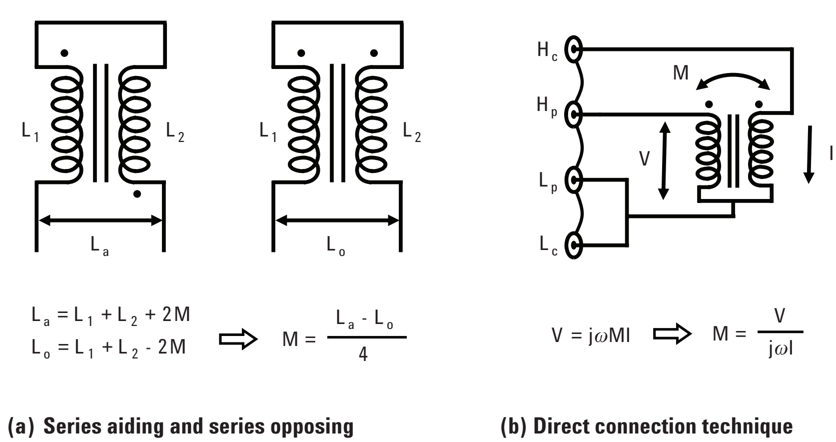

Figure 5-22. Mutual inductance measurement

5.3.4 Turns ratio (N)

Turns ratio (N) measurement technique, which can be used with general impedance measuring instruments, approximates the turns ratio (N:1) by connecting a resistor to the secondary as shown in Figure 5-23 (a). From the impedance value measured at the primary, the approximate turns ratio can then be calculated. Direct turns ratio measurement can be made with a network analyzer or built-in transformer measurement function (option) of the Agilent 4263B LCR meter. The turns ratio can be determined from the voltage ratio measurements for the primary and the secondary, as shown in Figure 5-23 (b). The voltmeter (V_2) should have high input impedance to avoid affecting the secondary voltage. The properties of magnetic core and the effects of stray capacitance limit the applicable frequency range of the turns ratio measurement methods.

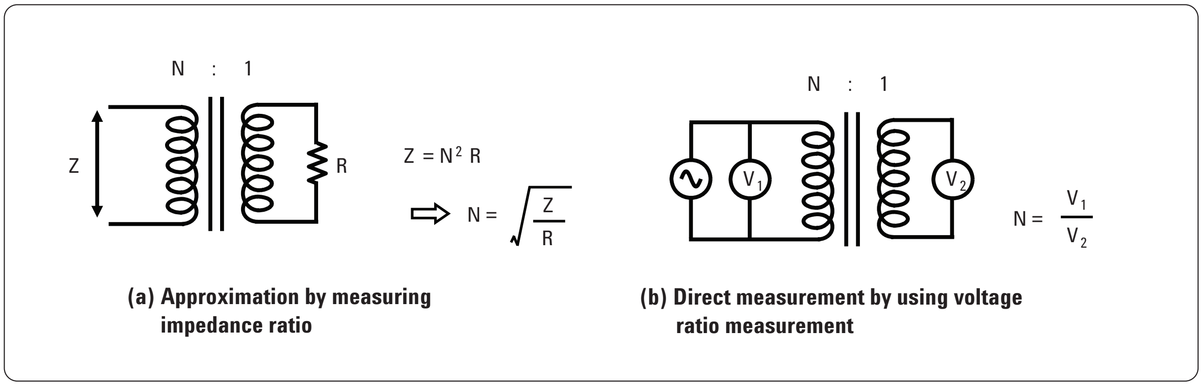

Figure 5-23. Turns ratio measurement