Measuring the temperature of windings using the resistance method

This method may be used to calculate the temperature rise of windings in transformers and motors.

This presentation does not attempt to cover details that may be different among several IEC based standards (e.g. 60335-1, 60601-1, 60950-1, 61010-1), such as acceptable limits, timing and the like. This is simply an overview of a method to obtain accurate results. Additional notes are provided to help in determining the actual temperature of the windings when it is not possible to take quick readings after disconnection from the heating test.

Some important guidelines:

1. If the expected resistance is less than 1.0 Ohm (either cold or hot), use a 4-wire milli-Ohm meter. If 1.0, Ohm or greater, you may use a 2-wire standard Ohm meter which has resolution of at least 0.1 Ohms.
2. The resistance method is only appropriate for uniformly shaped windings.
3. Your initial readings must be taken from all windings of the transformer when the sample is "dead cold". The best way to achieve this is to allow the sample to stabilize as room temperature for several hours (i.e. overnight).
4. Your test setup should be configured in such a way as to allow for a quick changeover from running power to taking resistance readings.
5. This method is suitable for "rated load" and "over load" conditions.

For the rest of this presentation, I assume you will be using a milli-Ohm meter.

Equipment needed:

1. A stable AC power source
2. Resistive loads appropriate for the transformer rating and winding configuration. (*You will need adequate loading for each secondary winding*)
3. A 2-wire Ohm meter or 4-wire milli-Ohm meter, as appropriate
4. AC Volt meter and AC Ammeter
5. A stop watch
6. A method for taking readings of the ambient air temperature.
7. A test sample

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Sample test data table:

xx.x	TABLE: Heating test, resistance method				
	Test voltage (V) ....:				—
	Ambient, t1 (°C) ....:				—
	Ambient, t2 (°C) ....:				—
Temperature rise of winding	R1 (Ω)	R2 (Ω)	Δ T (K)	Max. Δ T (K)	Insulation class
Primary					
Secondary #1					
Secondary #2					
Supplementary information:					

Test Voltage (V) is the nominal voltage rating of the transformer. If the transformer is rated for multiple voltages you must run separate tests for each one. Each secondary is separately loaded to its nominal rating, as verified by a volt meter and ammeter.

Ambient, t1 (°C) is the ambient temperature in the immediate area of the sample at the beginning of the test (with no power applied to the sample).

Ambient, t2 (°C) is the ambient temperature in the immediate area of the sample at the end of the test.

R1 (Ω) and **R2 (Ω)** are your resistance measurements corresponding to **Ambient, t1 (°C)** and **Ambient, t2 (°C)**, respectively.

Δ T (K) is the change in resistance as calculated:

$$\Delta T = \frac{R2}{R1}(k+t1)-(k+t2)$$

Note: *k*=234.5 for copper windings and *k*=225.0 for aluminum windings

Max. Δ T (K) is the maximum allowable change in resistance specified in the applicable standard

Insulation Class is the letter designation for the insulation material used in the construction of the transformer. Typical are Class A (105 °C), Class B (130 °C), and Class H (180 °C); check the applicable safety standard for correct application and other available insulation classes.

Supplementary information should describe your test setup in enough detail to allow future tests to duplicate your results accurately. Include details such as voltage, line frequency, load bank values for each secondary, duration of test and any other pertinent information. Do not simply copy the test requirements from the safety standard.

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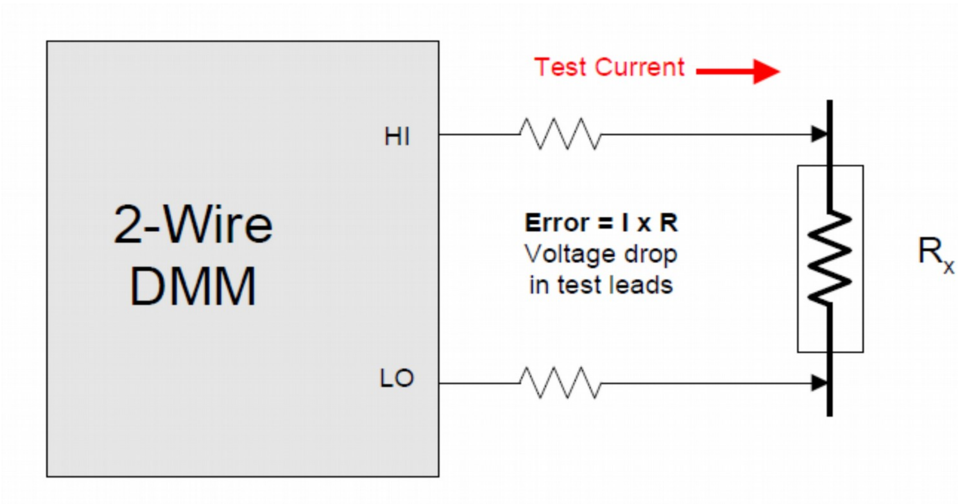
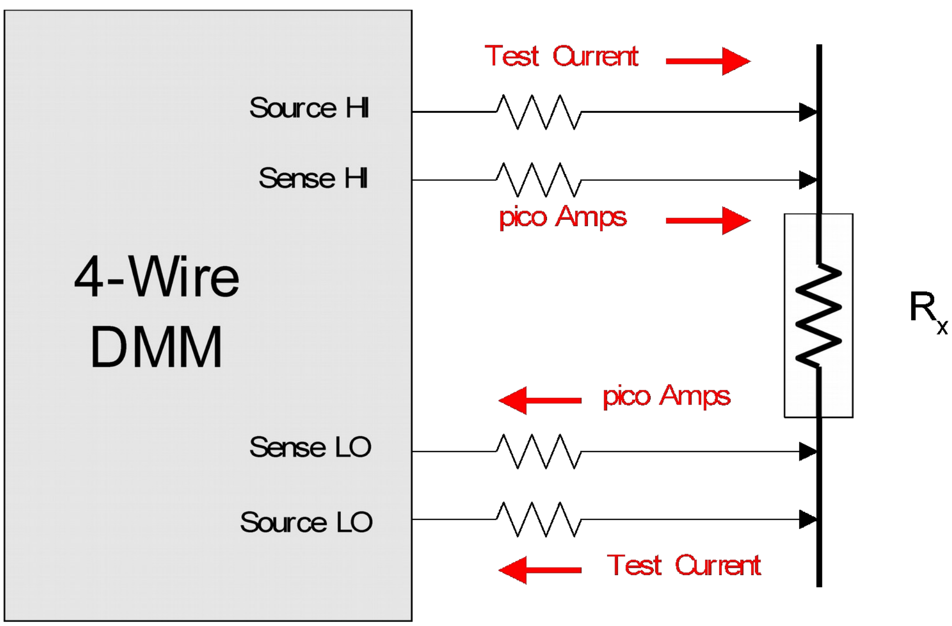
The purpose of 4-Wire or Kelvin measurements:

A standard 2-wire resistance measurement includes the series resistance of the test leads. When the resistance of the device being tested is nearly as low as the test leads themselves, you will get erroneous values.



The purpose of a 4-wire test is to eliminate the added resistance of the test leads from your results.



Note: 4-wire milli-Ohm meters are normally equipped with test clips called “Kelvin Clips” and are specially designed for this type of testing.

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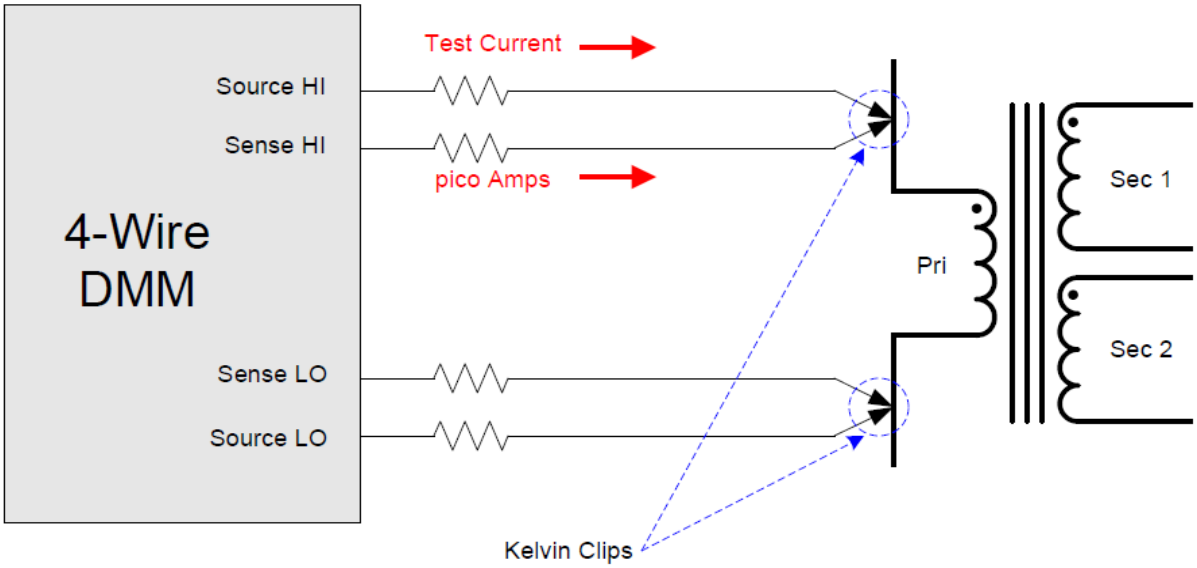
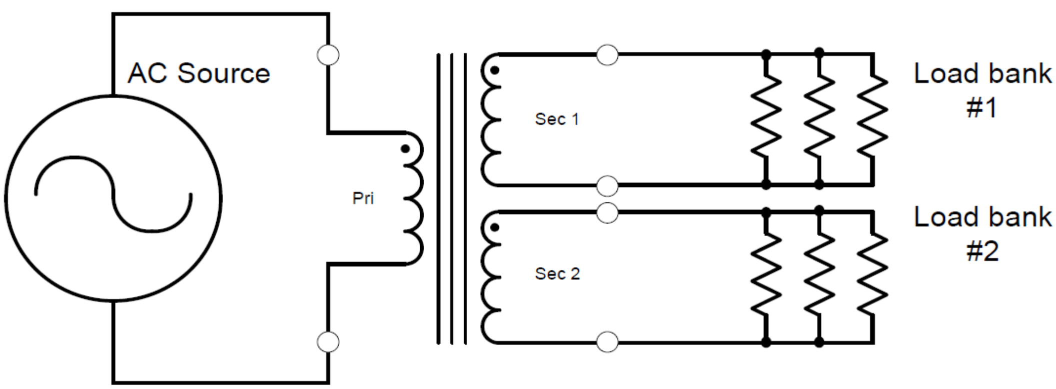
Measuring the transformer initial winding resistance (cold):



1. Repeat this measurement for every winding (Primary, Secondary 1, Secondary 2, etc.) record your results in the **R1 (Ω)** column.
2. Record the ambient temperature, **Ambient, t1 (ºC)**

The heating test:



1. This is one configuration for the heating test. If both secondaries are of identical configuration and ratings, it is possible wire the secondaries in series to combine resistive loads into a single bank.
2. If possible, try to configure transformer windings for easy disconnection and quick connection of the milli-Ohm meter.
3. Follow the instructions provided in the applicable safety standard for determining thermal stability of the transformer while heating. If necessary, it is possible to attach a thermocouple to the body of the transformer to make an estimation of when thermal stability has been reached. In this case a thermal data logger is required.

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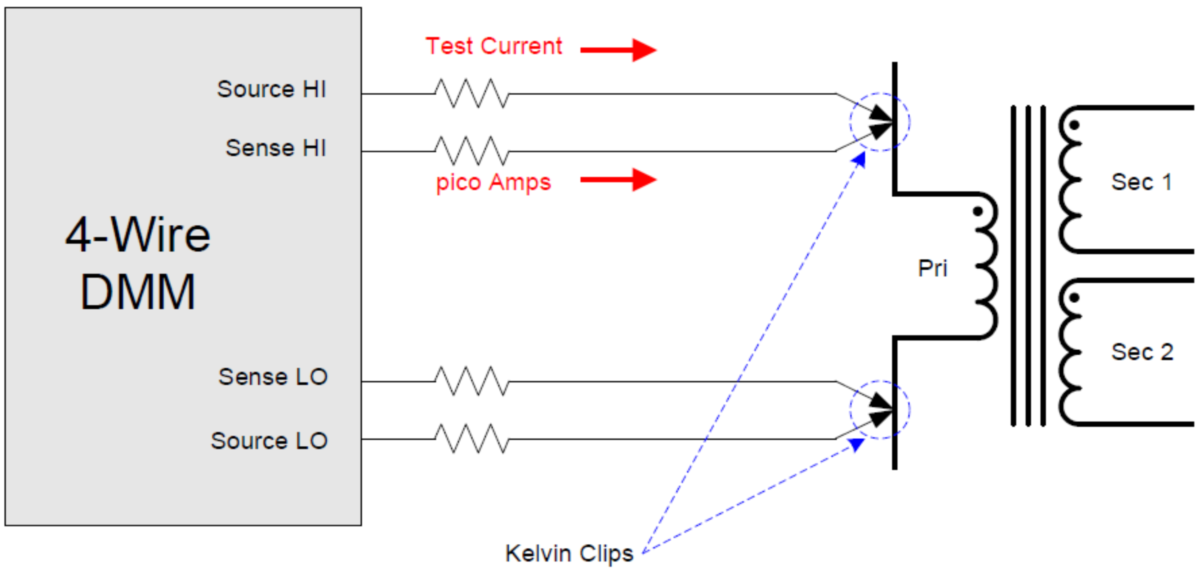
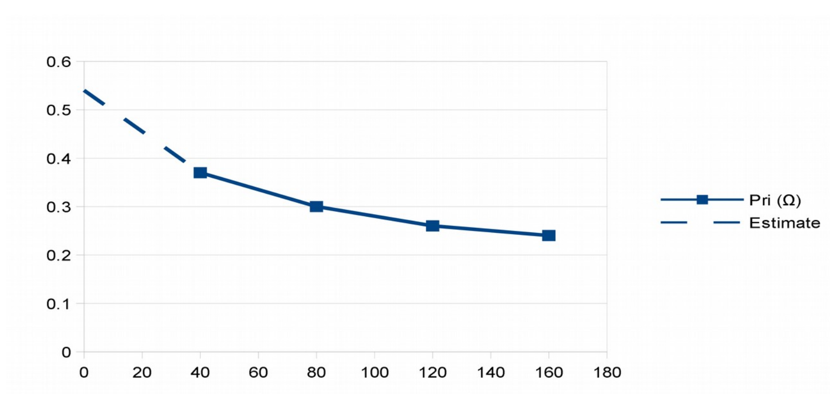
Final readings:

For this section, it may be helpful to have another person on hand to assist with time keeping.

1. At the same time you remove power from the heating test, start the stopwatch.
2. Quickly disconnect the transformer and connect to the milli-Ohm meter
3. For each winding in turn, take a resistance reading with the milli-Ohm meter, record the associated ambient (if it has changed) and the time on the stopwatch.



4. If you suspect a significant drop in winding temperature before your first measurement, take a few more readings of each winding, in sequence, at regular intervals and record their respective times. For example:
   - If the three windings are first measured at 40 seconds, 50 seconds and 60 seconds, wait for the next multiple of 40 seconds (80 seconds from the start) and record all three again.
   - Repeat this at least three times and five times if practical.
   - After multiple readings are taken plot the results in a spreadsheet and extrapolate back to the start time while keeping in mind the exponential nature of the cooling profile.
   - A curve fitting program may be useful for reverse extrapolation.



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