Chapter 10

Testing, Evaluation, and Quality Assurance

Table of Contents

Introduction

Transformer testing is the only way to determine verification of how effective the design and fabrication is. Transformer tests can be grouped into two categories: a functional test and a reliability test. Functional tests are those that verify the design criteria and specification requirements, while reliability tests are defined as those, which determine the adequacy of the mechanical and insulation system.

Electrical Tests

The electrical tests performed on a magnetic component are to insure that they will meet the overall specification. A transformer or inductor is designed to meet a specific requirement, such as a primary inductance magnetizing current. The transformer is also required to provide a specified voltage and current with the proper phasing. Some transformers are required to operate over a wide frequency range. There are many electrical tests that have to be performed to insure that the transformers that are fabricated, will meet the specification. The electrical tests are used to catch things such, as a wrong or bad core, a wrong wire size, (AWG), incorrect turns, and winding procedure.

Electrical Tests to Perform

Magnetizing Current

The magnetizing current is an indication on whether the transformer or inductor has the correct core, the correct core material, and/or the correct gap.

Inductance Measurement

The inductance measurement is an indication on whether the transformer or inductor has the correct core, the correct core material, and/or the correct gap.

Turns-Ratio

The turns-ratio test will assure the proper terminal voltage.

Winding Resistance

The winding resistance test is to insure the correct wire size and the proper winding procedure was used.

Phasing

Phase testing is a very important parameter in many transformer applications.

Resonant Frequency

The resonant frequency is an indication of how the transformer is wound and what material is used. It also is an indicator regarding, whether or not the correct core, the correct core material, and/or the correct gap was used.

Primary to Secondary Capacitance

The primary to secondary capacitance is an indication of the winding method and materials used.

Voltage Breakdown

The voltage breakdown test is an indication on whether the transformer has the correct insulation and lead dressing.

Fabrication Tests

The fabrication tests performed on a magnetic component are used to insure that the construction and workmanship procedures have been followed. Fabrication procedures must be followed to minimize contamination from preservatives, such as oils and grease, that could collect foreign objects. If transformers or inductors are to be handled, then gloves should be worn to minimize contamination from body oils and salts. There are other contaminations, such as flux, and/or solder splashes that could lead to a premature failure.

Fabrication Tests to Perform

Megger Test

The Megger Test is an insulation resistance test. This test is to detect any leakage resistance caused by contamination. The Megger Test is performed, at either 50 or 500 volts dc, depending on the requirement. The Megger Test is normally performed between all combinations of isolated elements, such as the primary, secondaries, the core, shields, enclosures, and mounting hardware. The normal insulation reading is about 20,000 meg-ohms.

Hi-Pot Test

The Hi-pot Test is an electrical strength test. This test is to check for voltage breakdown caused by poor or inadequate insulation, lead dressing, and/or foreign particles. The Hi-pot test is normally performed with a potential of twice the operating voltage, plus 1000 volts ac, depending on the requirement. The Hi-pot test is performed between all combinations of isolated elements, such as the primary, secondaries, the core, shields, enclosures, and mounting hardware. The Hi-pot voltage is normally applied for one minute.

Environmental Tests

The Environmental Test, such as shock, vibration, temperature range, temperature shock, and temperature burn-in, (life test), is normally set by project.

Test Guidelines

B-H Loops

Testing transformers and inductors always stays within the linear portion of the B-H loop, as shown in Figure 10-1.

Frequency

Evaluation testing of transformers and inductors should be done at more than one frequency and at more than one voltage level.

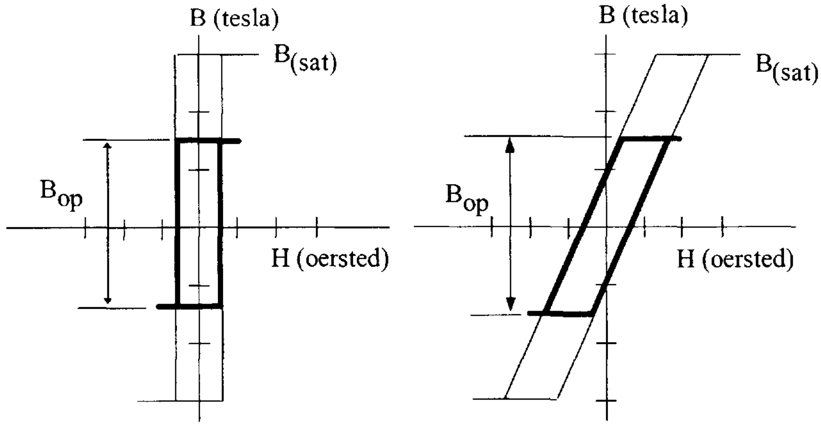


Figure 10-1. Operating in the Linear Portion of the B-H Loop.

Test Fixture

There should be a special test fixture for testing and evaluating transformer and inductors. This test fixture should be permanent and not torn down after each test. This way, if the test has to be run again, it is always best to use the same components to duplicate the test.

Breadboard Components

It is not wise to impregnate or pot the original set of breadboard magnetic components used to evaluate the design. The reason is the potting material could have an influence on the performance of the magnetic components and the performance of the circuit they are used in. Once they are potted, going back to the original set of conditions is impossible. It is best to have an additional set wound to impregnate and pot, and leave the originals alone.

Test Conditions

Applied Voltage

The test voltages and conditions for the magnetic component should be in the specification control drawing, (SCD). If there is no reference to voltage or test conditions, then the test engineer should consult with the cognizant engineer. If this is not feasible, and the magnetic component is of a simple design, then, the test engineer should calculate the required applied voltage. The test should be performed at a frequency of 1.0 kHz, and a flux level of about 0.05 tesla. The applied voltage during the test of the magnetic component should be a clean and undistorted sine wave at all times.

Equipment

Care must be taken when interpreting test results. There is always a chance for a misapplication, where a piece of equipment is used beyond its capacity. An example would be an instrument bridge being used to excite an inductor, with a large gap requiring more power, beyond the instruments deliverable capability. Reading the manual is important to be sure the test instrument is operating within its capability.

Turns Ratio Test

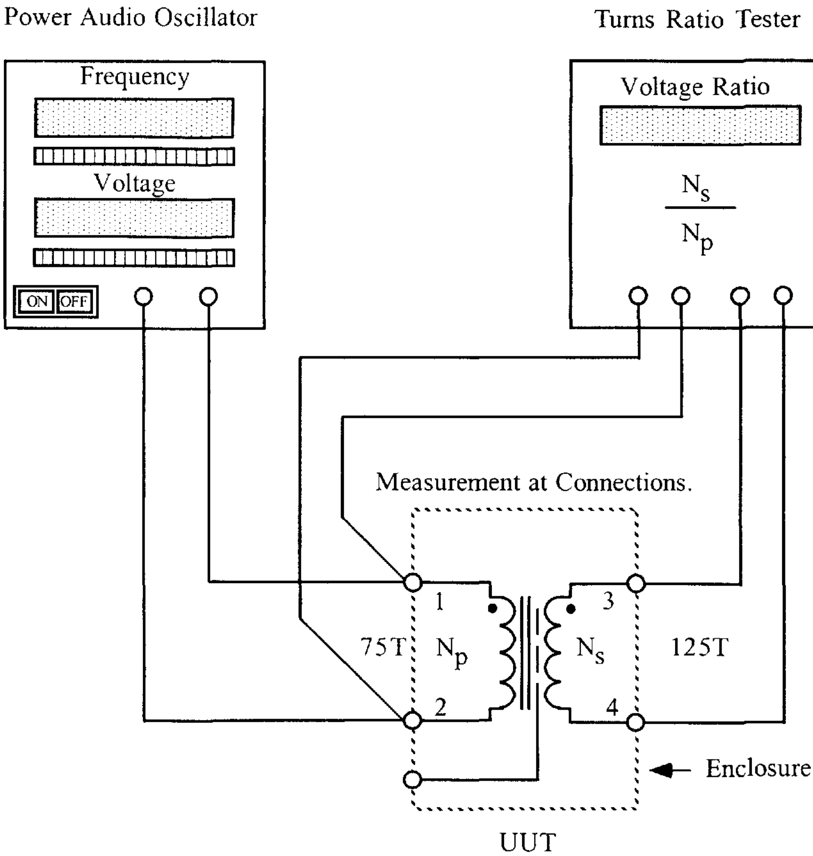


Figure 10-2. Test Setup for a Turns Ratio Test.

Equipment

1. Power Audio Oscillator
2. Voltage Ratio Meter

Test (See the information on Test Conditions).

The test setup for making turns ratio test is shown in Figure 10-2. Apply the voltage to Terminals, (1-2) and the read secondary on terminals, (3-4):

$$\text{Ratio} = \frac{N_s}{N_p}$$

$$\text{Ratio} = \frac{125}{75}$$

$$\text{Ratio} = 1.6666$$

Turns Ratio Test Using Voltage

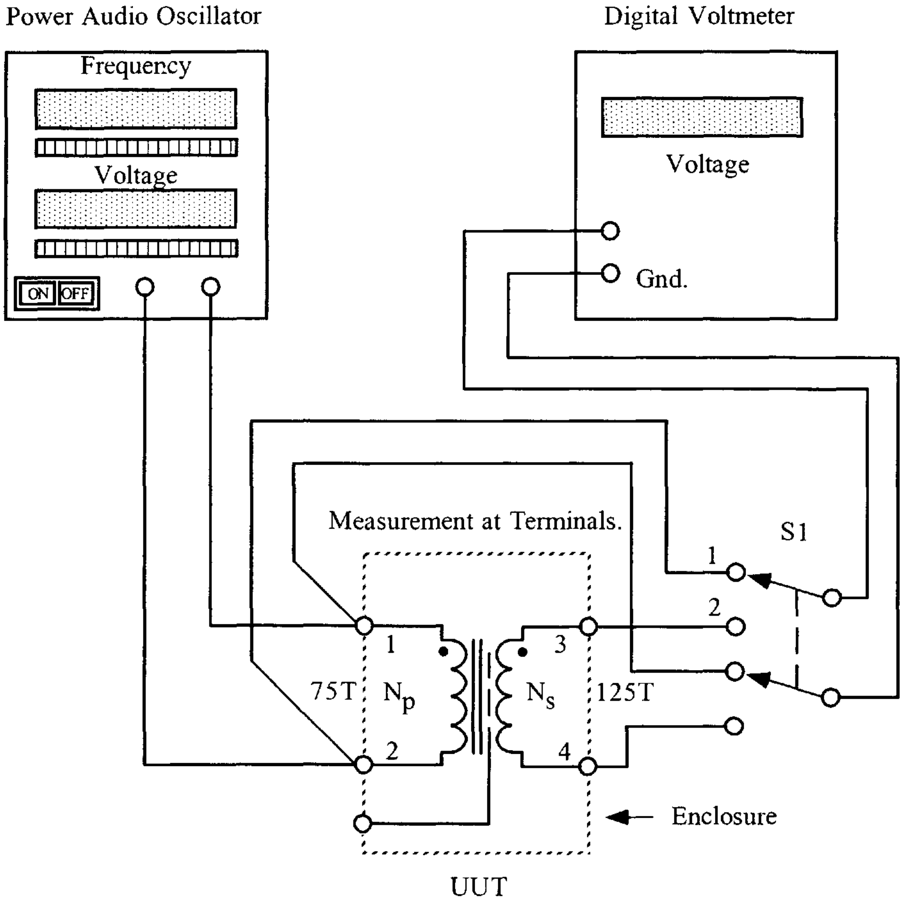


Figure 10-3. Test Setup for a Turns Ratio Test, Using Voltage.

<u>Equipment</u>

1. Power Audio Oscillator
2. Voltage Meter
3. S1, DPST (break before make)

<u>Test</u> (See the information on Test Conditions).

There are two methods to accomplish this type of turns ratio test shown in Figure 10-3: 1. Apply a voltage equal to the primary turns, such as 0.75 volts. Then, read the secondary voltage of 1.25 as turns, directly. 2. Apply the voltage to terminals, (1-2), and read the secondary voltage, (3-4). Use a calculator and divide the primary voltage into the secondary.

$$\text{Ratio} = \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\text{Ratio} = \frac{125}{75} = \frac{1.666}{1}$$

$$\text{Ratio} = 1.666$$

Primary Inductance and Leakage Inductance Measurements Using a Bridge

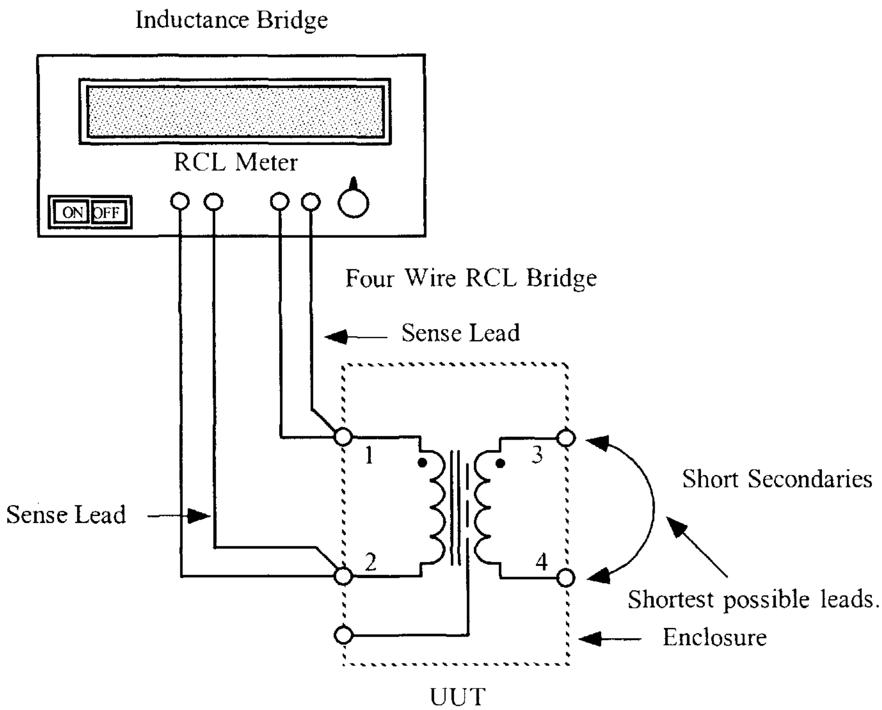


Figure 10-4. Inductance Measurements, Using a Four-Wire Bridge.

<u>Equipment</u>

1. Four-Wire, RCL Bridge

<u>Test</u> (See the information on Test Conditions).

Connect the leads to terminals, (1-2), as shown in Figure 10-4, and read the inductance directly on the RCL meter. The two sense leads will compensate for the long leads. This way, the bridge will measure right at the terminals. Instruments of this type, with four leads coming from the instrument, provide a more accurate reading.

Primary Inductance and Leakage Inductance Measurements Using Current

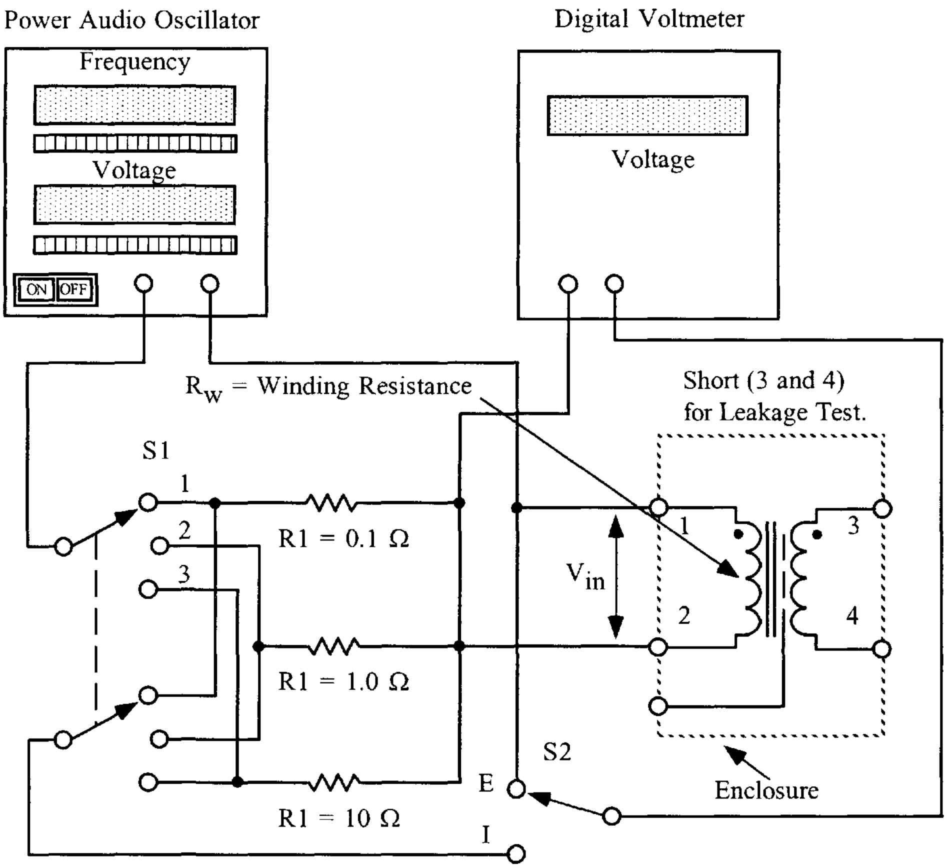


Figure 10-5. Test Setup for Measuring Magnetizing Current.

Equipment

1. Power Audio Oscillator
2. Digital Voltmeter
3. S1, 2 pole 3 position (break before make)
4. S2, SPST
5. R1, 0.10Ω, 1.0Ω, 10Ω, 1% wire wound (non-inductive)
6. Winding Resistance, R_w

Test (See the information on Test Conditions).

Place the switch, S2, in position E, and apply the input voltage V_{in}, as shown in Figure 10-5. Place switch, S1, in a position that provides the best voltage reading with the lowest resistance value of R1.

Test Specification

Frequency, f = 1 kHz
V_{in} = 6 volts
R1 = 1 Ω
R_w = 2 Ω
V_{R1} = 0.150 volts

Step 1. Calculate the input current, I_{in}.

$$I_{in} = \frac{V_{R1}}{R1}, \quad [\text{amps}]$$
$$I_{in} = \frac{0.15}{1}, \quad [\text{amps}]$$
$$I_{in} = 0.150, \quad [\text{amps}]$$

Step 2. Calculate the circuit impedance, Z.

$$Z = \frac{V_{in}}{I_{in}}, \quad [\text{ohms}]$$
$$Z = \frac{6}{0.15}, \quad [\text{ohms}]$$
$$Z = 40, \quad [\text{ohms}]$$

Step 3. Calculate the equivalent resistance, R_X.

$$R_x = R1 + R_w, \quad [\text{ohms}]$$
$$R_x = 1 + 2, \quad [\text{ohms}]$$
$$R_x = 3, \quad [\text{ohms}]$$

Step 4. Calculate the reactance, X_L.

$$X_L = \sqrt{Z^2 - R_x^2}, \quad [\text{ohms}]$$
$$X_L = \sqrt{(40)^2 - (3)^2}, \quad [\text{ohms}]$$
$$X_L = 39.9, \quad [\text{ohms}]$$

Step 5. Calculate the inductance, L.

$$L = \frac{X_L}{2\pi f}, \quad [\text{henrys}]$$
$$L = \frac{(39.9)}{(6.28)(1000)}, \quad [\text{henrys}]$$
$$L = 0.00635, \quad [\text{henrys}]$$

Inductance Measurement with DC

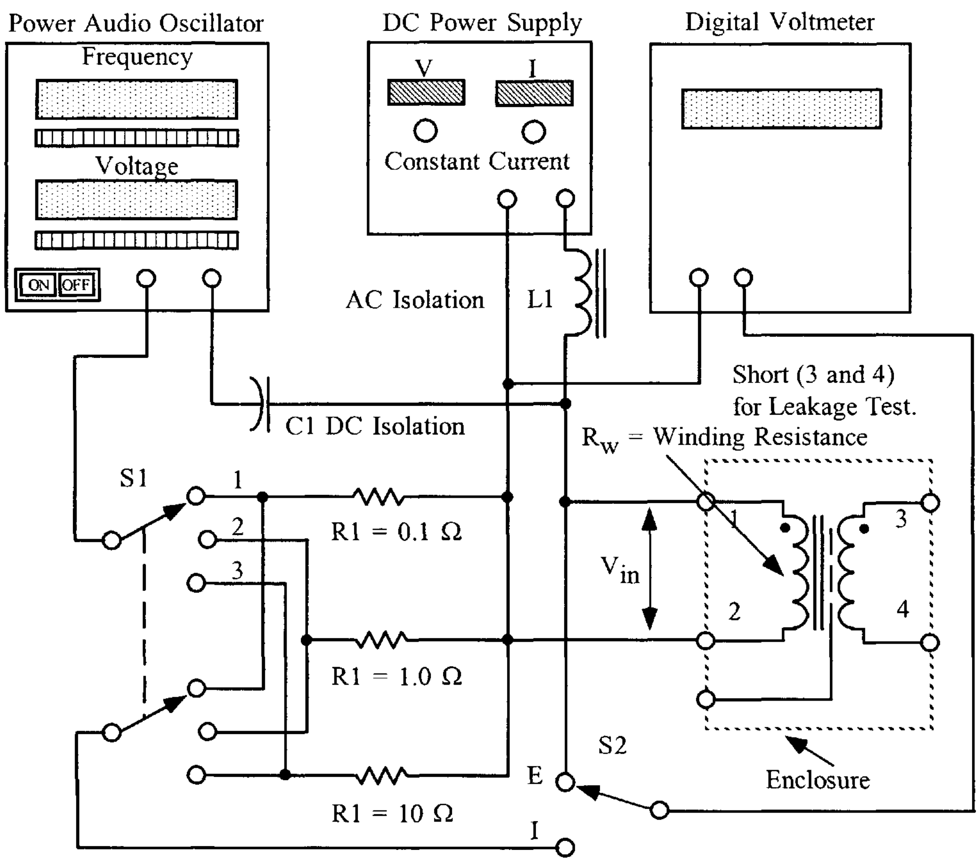


Figure 10-6. Test Setup for Measuring Magnetizing Current.

<u>Equipment</u>

1. Power Audio Oscillator
2. Digital Voltage Meter
3. DC Power Supply, 0 – 10 amps
4. S1, 2 pole, 3 position, (break before make)
5. S2, SPST
6. R1, 0.10Ω, 1.0Ω, 10Ω, 1% Wire Wound (non-inductive)
7. Winding Resistance, R_w
8. C1, dc Blocking Capacitor
9. L1, ac Isolation Inductor is designed to minimize the ac current driven back into the power supply.

<u>Test</u> (See the information on Test Conditions).

Place switch, S2, in position E and apply the input voltage, V_{in}, as shown in Figure 10-6. Place switch, S1, in a position that provides the digital voltmeter with the best resolution with lowest resistance value of R1. Adjust the constant current, power supply to the current as specified in the Specification Control Drawing, (SCD).

Test Specification

Frequency, f = 50 kHz
V_{in} = 3 volts
R1 = 1 Ω
R_w = 0.15 Ω
V_{R1} = 0.250 volts
I_{dc} = 3 amps

Step 1. Calculate the input current, I_{in}.

$$I_{in} = \frac{V_{R1}}{R1}, \quad \text{[amps]}$$
$$I_{in} = \frac{0.25}{1}, \quad \text{[amps]}$$
$$I_{in} = 0.250, \quad \text{[amps]}$$

Step 2. Calculate the circuit impedance, Z.

$$Z = \frac{V_{in}}{I_{in}}, \quad \text{[ohms]}$$
$$Z = \frac{3}{0.25}, \quad \text{[ohms]}$$
$$Z = 12, \quad \text{[ohms]}$$

Step 3. Calculate the equivalent resistance, R_x.

$$R_x = R1 + R_w, \quad \text{[ohms]}$$
$$R_x = 1 + 0.15, \quad \text{[ohms]}$$
$$R_x = 1.15, \quad \text{[ohms]}$$

Step 4. Calculate the reactance, X_L.

$$X_L = \sqrt{Z^2 - R_x^2}, \quad \text{[ohms]}$$
$$X_L = \sqrt{(12)^2 - (1.15)^2}, \quad \text{[ohms]}$$
$$X_L = 11.9, \quad \text{[ohms]}$$

Step 5. Calculate the inductance, L.

$$L = \frac{X_L}{2\pi f}, \quad \text{[henrys]}$$
$$L = \frac{(11.9)}{(6.28)(50000)}, \quad \text{[henrys]}$$
$$L = 0.0000379, \quad \text{[henrys]}$$
$$L = 37.9, \quad [\mu\text{h}]$$

Resistance Measurement Using a Bridge

(Measure Resistance >1Ω)

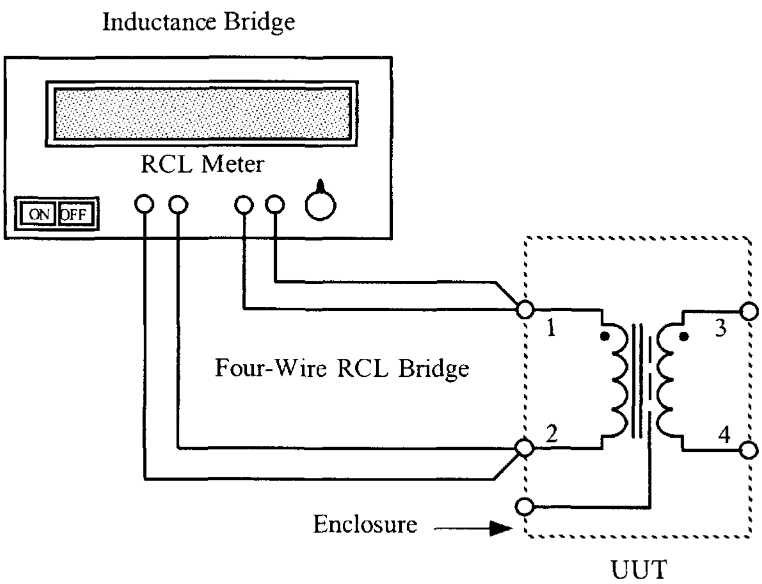


Figure 10-7. Resistance Measurements, Using a Four-Wire Bridge.

<u>Equipment</u>

1. Four Wire RCL Bridge

<u>Test</u> (See the information on Test Conditions).

Connect the leads to terminals, (1-2), as shown in Figure 10-7, and read the resistance, directly on the RCL meter. The two sense leads will compensate for the long leads. This way, the bridge will measure directly at the terminals. Instruments, that use four leads for measurement, will provide a more accurate reading.

Resistance Measurement Using Current

(Measuring Resistance, < 1.0 Ω)

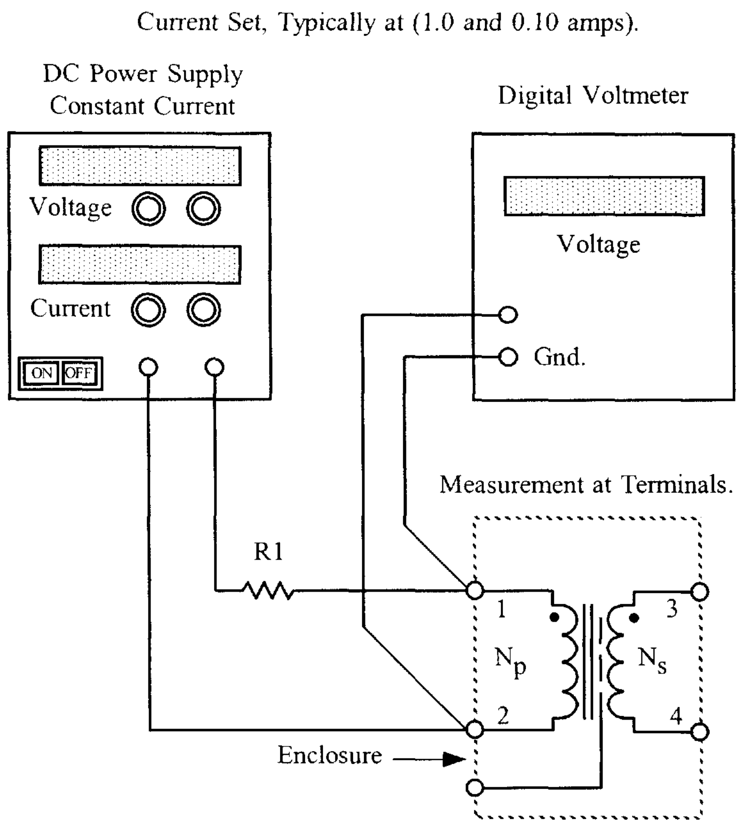


Figure 10-8. Resistance Measurements, Using a Constant Current Power Supply.

<u>Equipment</u>

1. DC Power Supply
2. Digital Voltmeter
3. R1, Calibration Resistor 1 Ω, 1% Wire Wound 5-10 Watt. The calibration resistor is used to provide an accurate current reference, in case the power supply is not capable of it.

<u>Test</u> (See the information on Test Conditions).

Connect the leads to terminals (1-2), as shown in Figure 10-8, and read the voltage, directly on the digital voltmeter. Using a current value of 1 amp will provide a direct resistance reading.

<u>Caution</u>

High currents on fine wire could cause overheating and damage.

Testing for Transformer Resonance

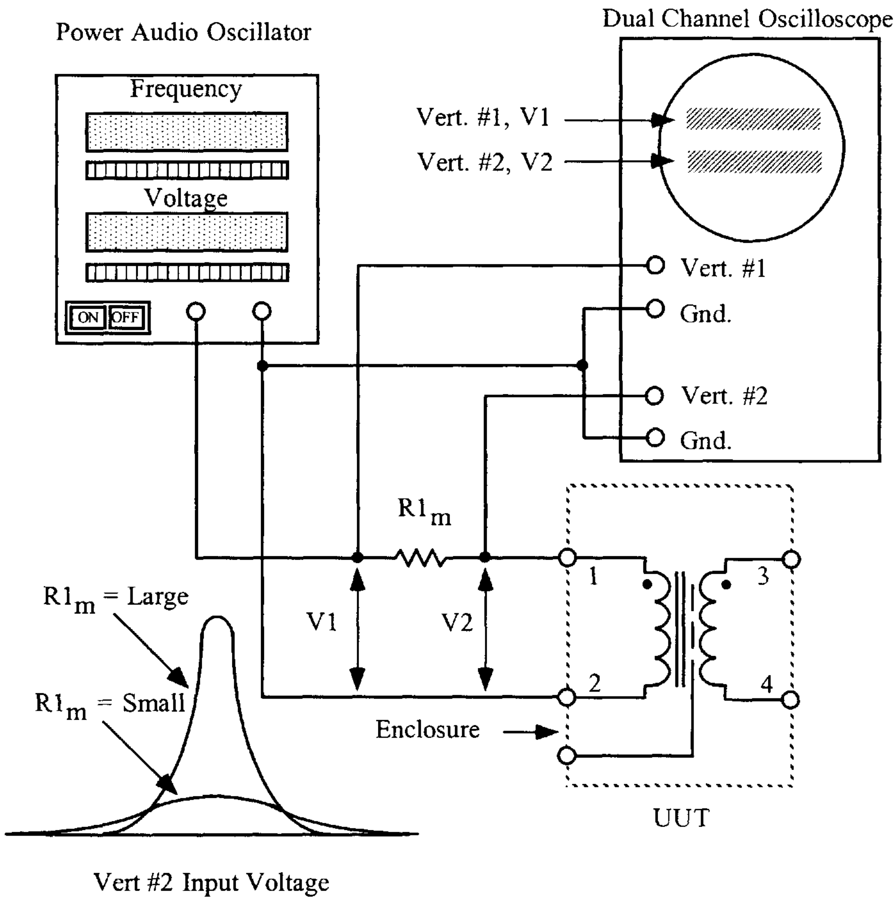


Figure 10-9. Circuit for Measuring Transformer or Inductance Self Resonates.

Equipment

1. Wide Band Power Oscillator
2. Dual Beam Oscilloscope
3. $R1_m$, Sense Resistor 250 - 1000 Ω, 5% Carbon 1 Watt.

Test (See the information on Test Conditions).

Connect the circuit, as shown in Figure 10-9. The voltage, V1, will be held constant and go to a vertical input, #1, of the oscilloscope. The voltage, V2, will go to a vertical input, #2, of the oscilloscope, starting at about 1 kHz sweep through the frequency, while keeping the voltage, V1, constant. The oscilloscope will monitor, V1 and V2. The voltage, V2, will change in amplitude, as the frequency is changed. As the frequency is increased, the voltage, V2, will start to rise and reach a peak value, and then start to decay. At this peak voltage, the transformer is at resonance.

Phase Testing

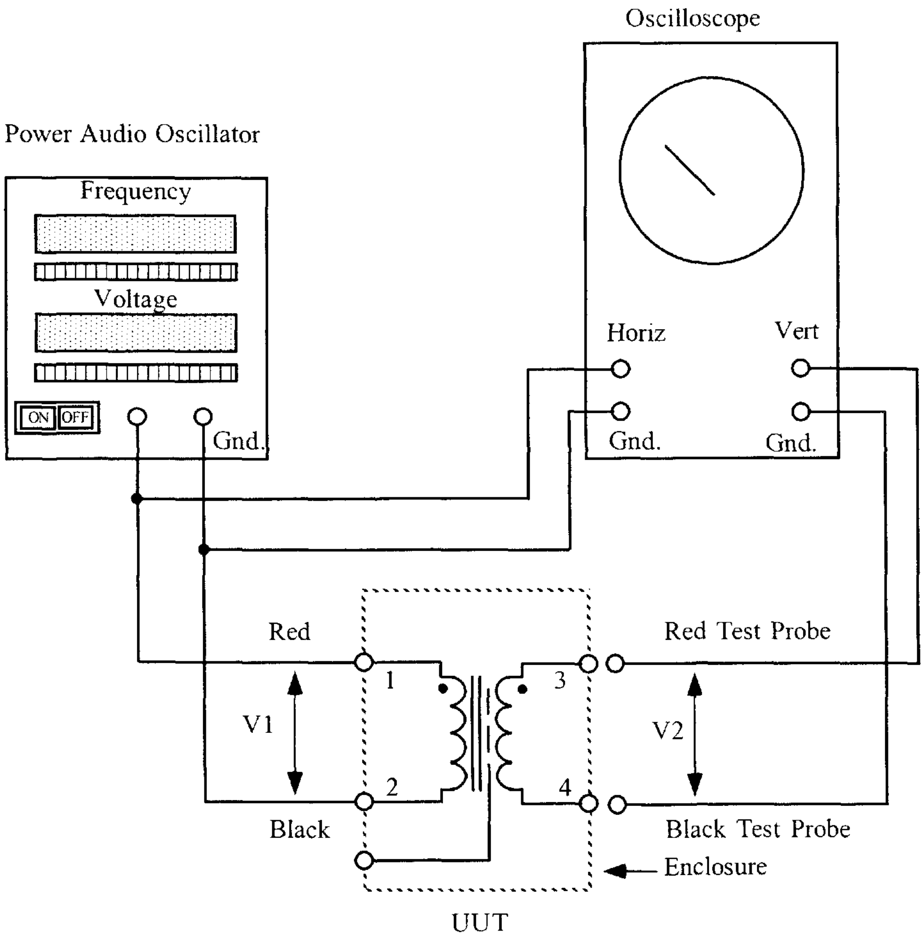


Figure 10-10. Test Circuit for Measuring the Transformer Winding Phase.

<u>Equipment</u>

1. Power Oscillator
2. Oscilloscope with Both Vertical and Horizontal Input.

<u>Test</u> (See the information on Test Conditions).

Connect the circuit, as shown in Figure 10-10. The voltage, V1, will be held constant and go to a horizontal input of the oscilloscope. The voltage, V2, will go to a vertical input of the oscilloscope. Place the, V2, Red Test Probe on the input, V1, Red. The oscilloscope will show a deflection to the left, indicating a start phase condition. If the trace is deflected in the other direction, then the phase is reversed.

Insulation Resistance Test

(Megger Test)

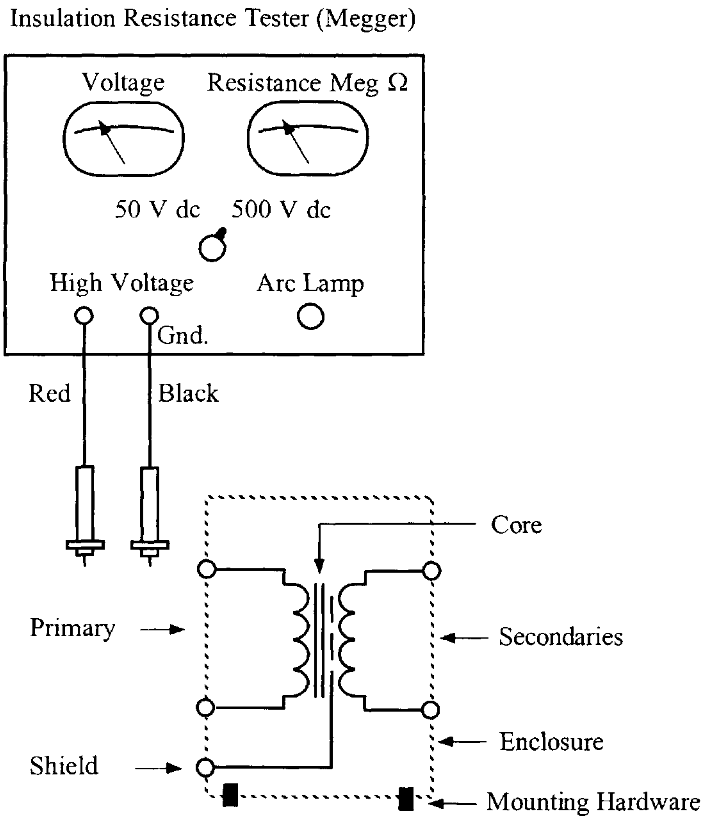


Figure 10-11. Setup for the Insulation, Resistance Test.

Equipment ***(Caution High Voltage)***

1. Insulation, Resistance Tester (Megger)

Test (See the information on Test Conditions).

An insulation resistance test circuit is shown in Figure 10-11. The Megger Test is performed at either 50 or 500 volts dc, depending upon the requirement. The Megger Test is normally performed between all combinations of isolated elements, such as primary, secondaries, core, shields, enclosures, and mounting hardware. The normal insulation reading is about 20,000 meg-ohms. The test voltages and conditions for the magnetic component should be in the Specification Control Drawing, (SCD). If there is no reference to voltage or test conditions, then the test engineer should consult with the cognizant engineer.

Voltage Breakdown Test

(Hi-Pot Test)

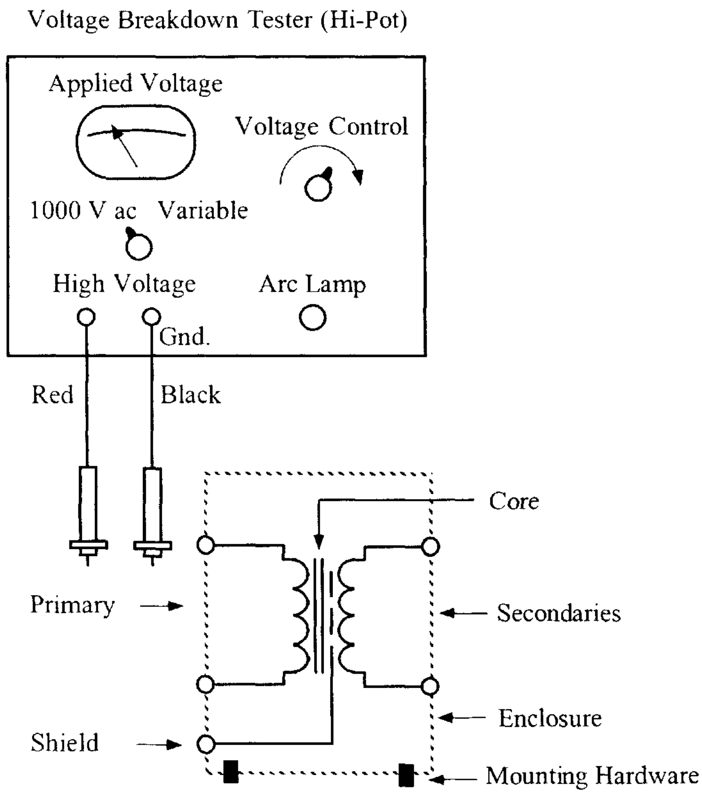


Figure 10-12. Setup for the Voltage Breakdown Test.

Equipment ***(Caution High Voltage)***

1. Voltage Breakdown Tester, (Hi-pot)

Test (See the information on Test Conditions).

Voltage breakdown test circuit is shown in Figure 10-12. The Hi-pot Test is normally performed with a potential of twice the operating voltage, plus 1000 volts ac, depending on the requirement. The Hi-pot Test is performed between all combinations of isolated elements, such as primary, secondaries, core, shields, enclosures, and mounting hardware. The Hi-pot voltage is normally applied for one minute. The test voltages and conditions for the magnetic component should be in the specification control drawing, (SCD). If there is no reference to voltage or test conditions, then the test engineer should consult with the cognizant engineer.

Primary to Secondary Capacitance Measurement

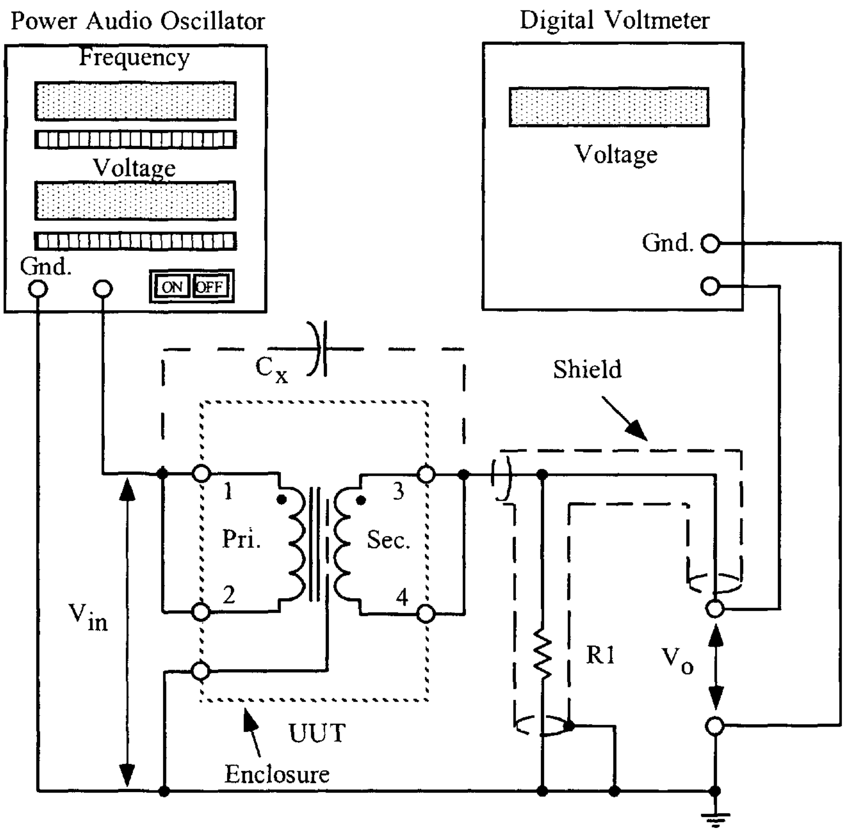


Figure 10-13. Test Circuit for Measuring Primary to Secondary, ac, Leakage Current.

<u>Equipment</u>

1. Power Audio Oscillator
2. Digital Voltmeter

<u>Test</u> (See the information on Test Conditions).

Connect the leakage current test circuit, as shown in Figure 10-13. The test voltages and conditions for the magnetic component should be in the Specification Control Drawing, (SCD). If there is no reference to voltage or test conditions, then the test engineer should consult with the cognizant engineer.

<u>Test Specification</u>

Frequency, f = 1.0 kHz
V_{in} = 10 volts
V_o = 100 micro-volts
R1 = 50 Ω

Step 1. Calculate the reactance of the capacitor, X_c.

$$X_c = R1\sqrt{\left(\frac{V_{in}}{V_o}\right) - 1}, \quad [\text{ohms}]$$

$$X_c = (50)\sqrt{\left(\frac{10}{0.005}\right) - 1}, \quad [\text{ohms}]$$

$$X_c = 2236, \quad [\text{ohms}]$$

Step 2. Calculate the circuit capacitance, C_x.

$$C_x = \frac{1}{2\pi\, f\, X_c}, \quad [\text{farads}]$$

$$C_x = \frac{1}{(6.28)(1000)(2236)}, \quad [\text{farads}]$$

$$C_x = 7.12\left(10^{-8}\right), \quad [\text{farads}]$$

$$C_x = 712, \quad [\text{pf}]$$

Testing Core Permeability

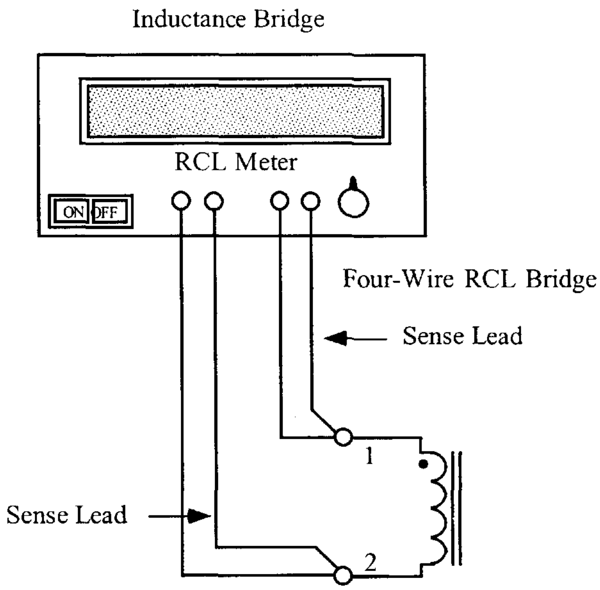


Figure 10-14. Inductance Measurements, Using a Four-Wire Bridge.

Equipment

1. Four Wire RCL Bridge

Test (See the information on Test Conditions).

Connect the leads to terminals, (1-2), as shown in Figure 10-14, and read the inductance directly on the RCL meter. The two sense leads will compensate for the long leads. This way the bridge will measure directly at the terminals. Instruments, that use four leads for measurement, will provide a more accurate reading.

Testing the permeability of magnetic cores can best be done on toroidal cores. Steps include: winding a few turns, measuring the inductance, and then simply calculating the millihenrys per 1000 turns. Testing power cores for permeability, by winding only a few turns, will not yield the correct permeability. The permeability, given by the manufacturers, is based on a fully-wound core. The error is caused by the fringing flux, due to the distributed gap. The error in permeability can be greater than 10%.

$$L_n = L_{(1000)} N^2 \left(10^{-6}\right), \quad \text{[millihenrys]}$$

L_n = inductance for N turns (mh)

$L_{(1000)}$ = nominal inductance (millihenry per 1000 turns)

$$L = \frac{0.4\pi N^2 A_c \mu \left(10^{-8}\right)}{(\text{MPL})}, \quad \text{[henrys]}$$

$$\mu = \frac{L(\text{MPL})\left(10^{-8}\right)}{0.4\pi N^2 A_c}, \quad \text{[permeability]}$$

Turns Ratio Test on Multi-Winding Inductors with Large Gaps

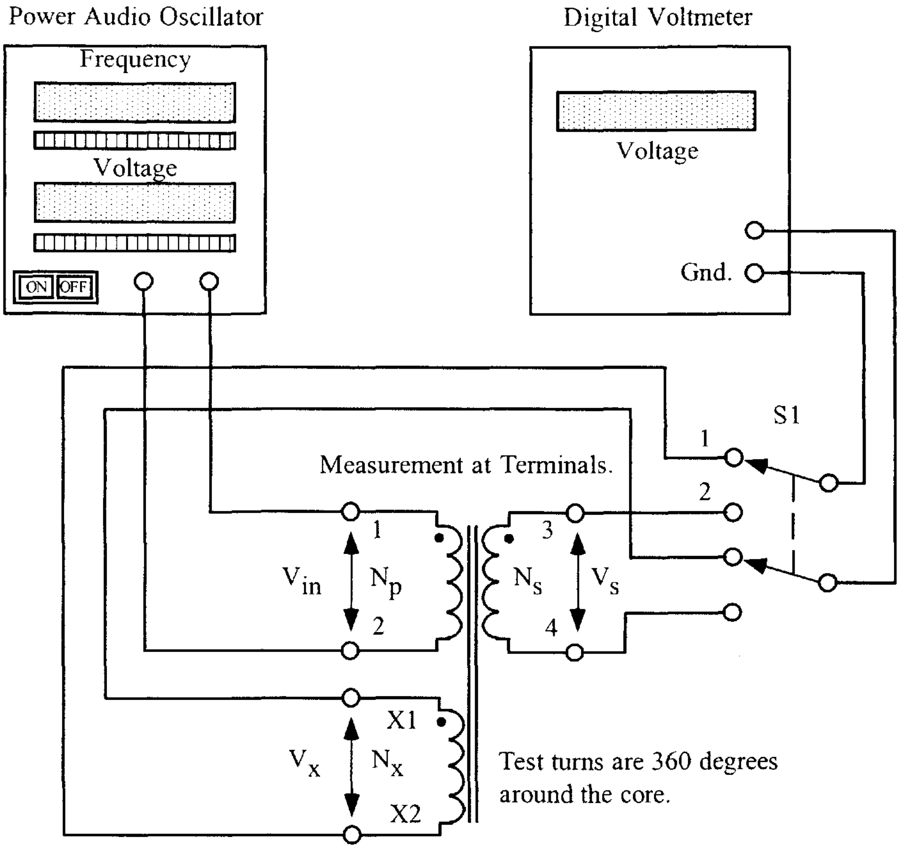


Figure 10-15. Test Setup for a Turns Ratio Test, Using a Tertiary Winding.

Equipment

1. Power Audio Oscillator
2. Digital Voltmeter
3. S1, DPST (break before make)

An accurate turns-ratio test on a multi-winding inductor is very difficult, due to winding resistance and leakage inductance. If the primary inductance is low, it results in a high excitation current, depending on the frequency. The test-operating frequency must stay well-below the resonant frequency. The resultant voltage drop, V_R, due to the primary resistance, is caused by a high excitation current, and the voltage drop, V_L, due to the leakage inductance, does not get transferred by the primary, as shown in Figure 10-16.

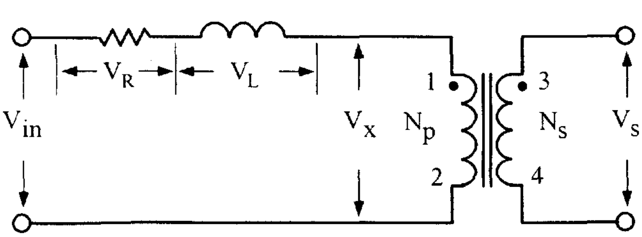


Figure 10-16. Primary Circuit and its Parasites.

Test (See the information on Test Conditions).

Add a tertiary winding. An example would be: Wind 10 turns, N_x, preferably 360 degrees around the core. This will be the reference winding. Place S1 in position 1. Then apply the input voltage, V_{in}, to terminals, (1-2), and read the tertiary voltage, V_x, at (X1–X2). Adjust the applied input voltage, V_{in}, until the voltage, V_x, equals 1 volt. Place S1 in position 2 and read the secondary voltage, V_s. The turns-ratio can be calculated using the tertiary winding, as shown below. The reverse has to be done to check the primary, N_p.

$$\text{Ratio} = \frac{N_s}{N_x} = \frac{V_s}{V_x}$$

Testing the Dynamic B-H Loop

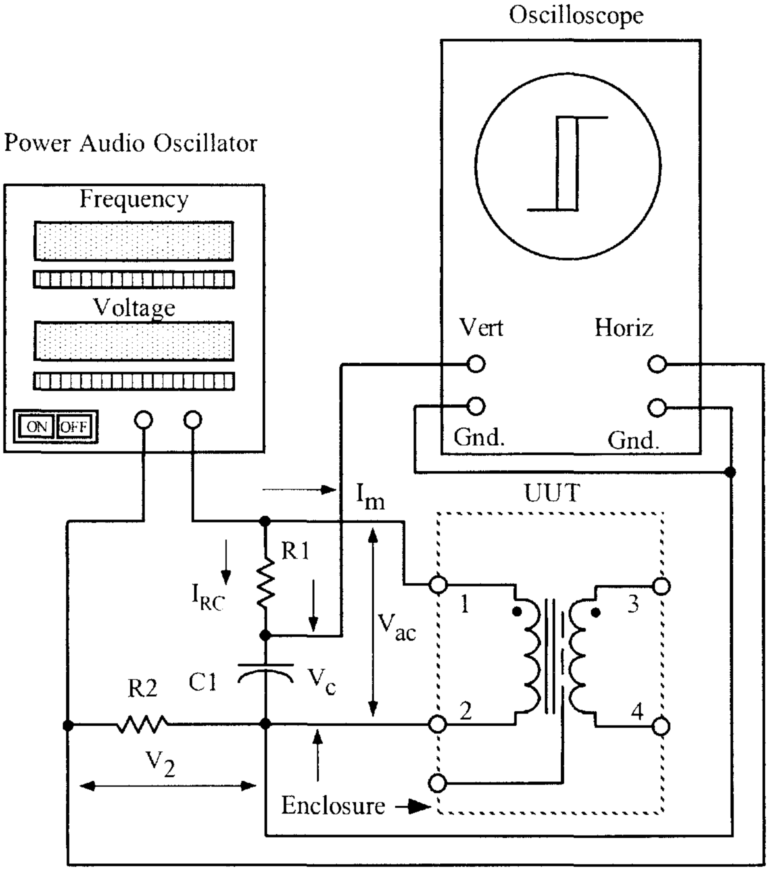
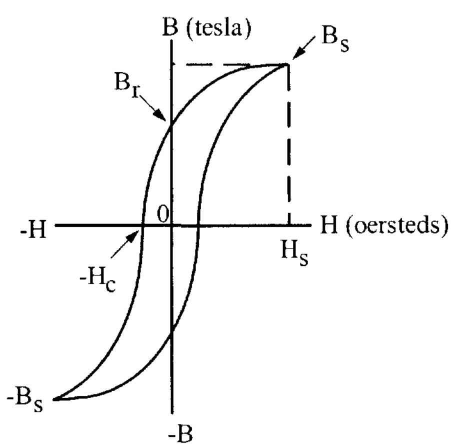


Figure 10-17. B-H Loop Test Circuit.

The test circuit, that is most commonly used to display the B-H loop on an oscilloscope, is shown in Figure 10-17. The dynamic hysterestis, or B-H loop, contains very important information about the magnetic component. The area within the B-H loop relates to losses, and the amplitude relates to flux density, as shown in Figure 10-18.



B The flux level in tesla.
B_r The remanence flux in tesla.
B_s The saturated flux in tesla.
H Magnetizing force in oersteds.
H_s The magnetizing force at saturation in oersteds.
H_c The coercivity force in oersteds.

Figure 10-18. Typical B-H Loop.

The excitation current, I_m, causes a magnetic force in the magnetic component:

$$I_m = \frac{H(MPL)}{0.4\mu N}, \quad \text{[amps]}$$

The voltage drop across R2 is proportional to the excitation current, as long as the current through R1 and C1 is:

$$I_{RC} = \frac{I_m}{100}, \quad \text{[amps]}$$

The voltage drop, V_2, should be very small compared to V_{ac}:

$$V_2 = \frac{V_{ac}}{100}, \quad \text{[volts]}$$

Then:

$$\mathrm{R2} = \frac{V_{ac}}{100 I_m}, \quad \text{[ohms]}$$

The series network of R1 and C1 perform the integration of the applied voltage. The resistance should be very large compared to the impedance of the capacitor at the operating frequency:

$$\mathrm{R1} = \frac{100}{\omega C}, \quad \text{[ohms]}$$

Then:

$$\mathrm{R1} = \frac{100 V_{ac}}{I_m}, \quad \text{[ohms]}$$

The measurement of the B-H loop is then:

$$B_m = \frac{V_c(10^4)}{4.44 N A_c}, \quad \text{[tesla]}$$

And

$$H = \frac{0.4\pi N}{(\mathrm{MPL})}\left(\frac{V_2}{\mathrm{R2}}\right), \quad \text{[oersteds]}$$

The voltage, V_c, across the capacitor, C1, is directly proportional to the, B_m, in tesla. The voltage, V_2, across the resistor, R2, is directly proportional to H in oersteds. The oscilloscope will have to be calibrated with a known, magnetic material.

Transformer and Inductor Test (Magnetic Component)

Test voltage shall be applied to the magnetic component undergoing the test in a vacuum chamber, at room pressure. Corona detection networks, as shown in Figure 10-19, shall be used in appropriate leads to monitor for corona or arcing. Typical corona and arcing waveforms are shown in Figure 10-20. With the voltage continuously applied, the air pressure shall be reduced to the lower limit, 5.0 x 10^{-4} torr, and then raised to 50 torr. This pressure shall be varied between the upper and lower limits several times for a minimum length of one hour in the critical pressure region. At the conclusion of the test, the voltage shall be removed, and the magnetic component shall be brought back to ambient room pressure. During the test, any evidence of corona or arcing shall be cause for rejection.

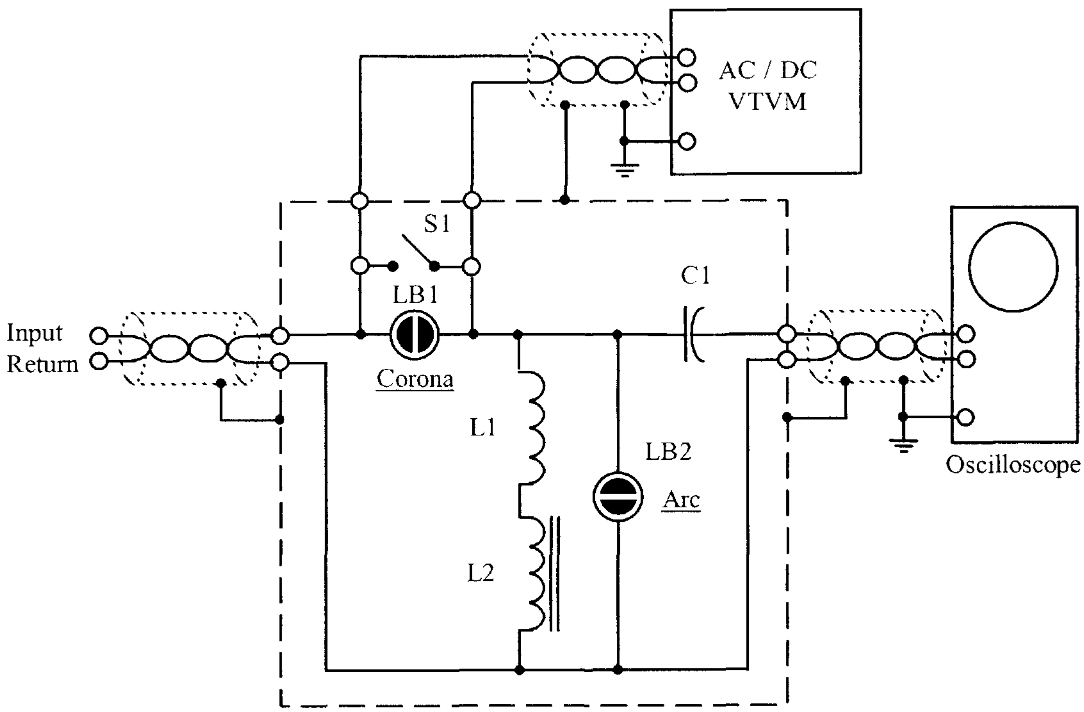


Figure 10-19. Corona Detection Network Schematic (CDN).

Parts' List

C1 = 300 pf 400 volt mica capacitor.

L1 = 2.6 mh +/- 20%, 40 ohms air-core.

L2 = 3.0 h +/- 20%, 225 ohms.

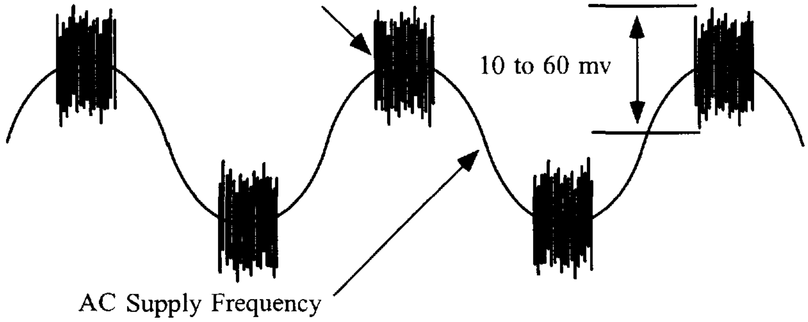
LB1= NE-2 Neon, AC/DC visual corona indicator.

LB2= NE-2 Neon, AC/DC visual arc indicator.

S1 = SPST, Bypass switch.

VTVM, AC/DC corona detector.

Scope, AC corona indicator.



Abrupt breaks in the scope trace or burst amplitudes, >5 volt pk-pk, indicates arcing, rather than corona.

Figure 10-20. Typical Oscilloscope, Corona Burst Pattern.

Test Configuration

The configuration for testing magnetic components shall be shown, as in Figure 10-21 and Figure 10-22. Electrical connectors and wire leads shall be corona proof, when the pressure is in the critical pressure region.

Transformer Mounting

Magnetic components, undergoing tests, shall be mounted in a similar manner to that in the subsystem, especially, with regards to, adjacent metallic surfaces, terminals, etc. Potting, coating or encapsulation shall be similar to that applied to the magnetic component part in the complete subsystem.

Interwinding Insulation

The insulation integrity between windings, between the winding and the core, and between the winding and the case, if one is used, or between windings and mounting inserts, if used, shall be tested by applying a voltage between the various windings, cores, etc., in accordance with Figure 10-21 and Table 10-1. The voltage shall be applied for a minimum time of 5 +/- 1 seconds.

Table 10-1

Working Voltage (dc plus peak ac)	Test (rms)
250 to 700 volts	2.8x working voltage
Above 700 volts	1.4x working voltage plus 1000

Intrawinding Insulation

Magnetic components shall be subjected to a voltage to cause twice the rated voltage to appear across all windings at the critical pressure region. The test voltage may be applied to any winding, as shown in Figure 10-22.

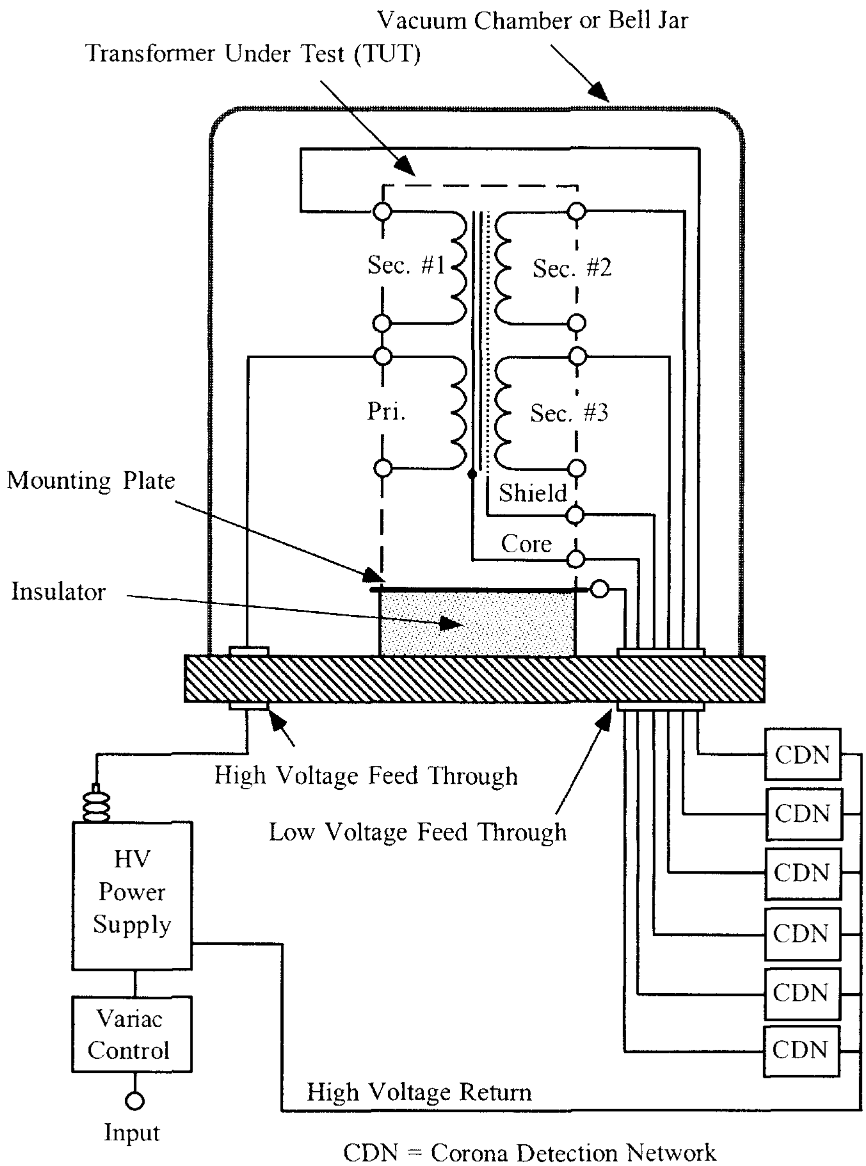


Figure 10-21. Transformer Interwinding, Voltage Breakdown Test.

Note:

1. Switch, S1, in the Corona Detection Network, shall be closed for this test.
2. Grounding type selector switch may be used with one Corona Detection Network.
3. CDN = Corona Detection Network. See Figure 10-19.

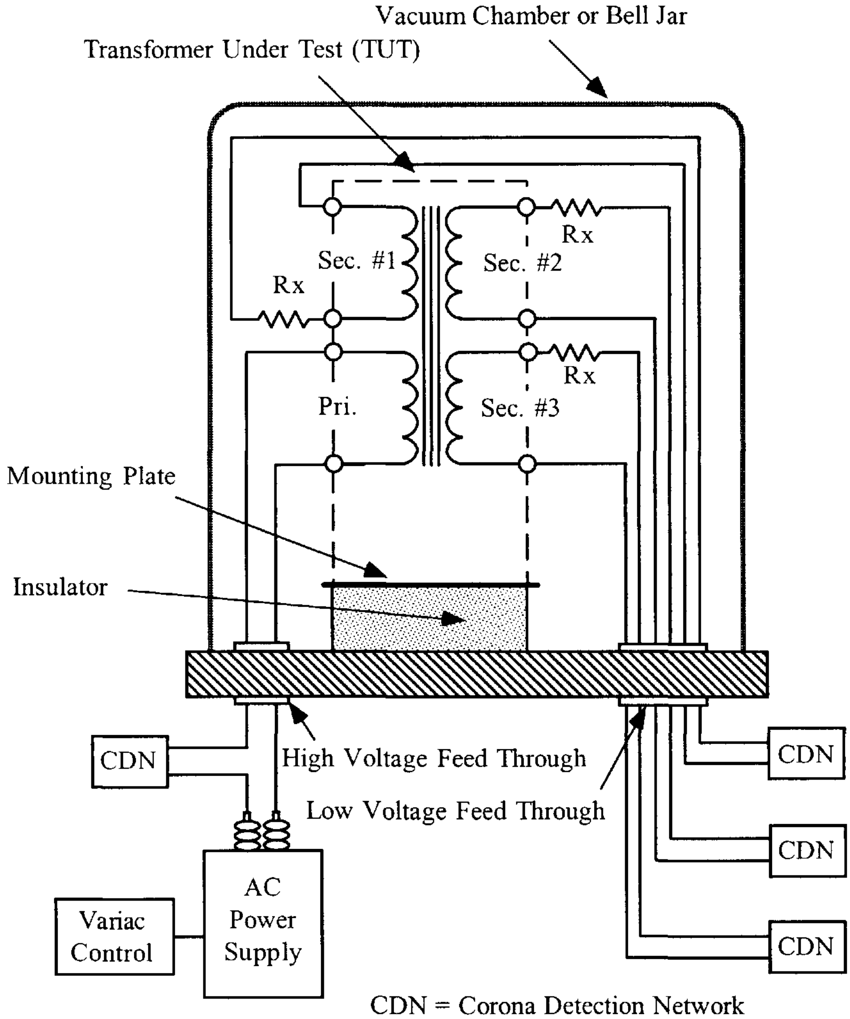


Figure 10-22. Transformer Intrawinding, Voltage Breakdown Test.

Note:

1. Resistors are loading, R's, for the secondary winding. (They may be located outside of the chamber).
2. Switch, S1, in the Corona Detection Network, shall be closed for this test.
3. The power supply, ac voltage, shall be twice-rated voltage for the winding, energized with the frequency raised, so that the ac current flowing is equal to, or less than the rated current.
4. The grounding type selector switch may be used with one Corona Detection Network.
5. CDN = Corona Detection Network. See Figure 10-19.

Care must be taken to terminate all of the magnetic components terminals so that external corona or arcing is prevented. Mountings and windings shall be grounded as they would be in service. The test frequency shall be far enough from any resonant frequency, so that voltages, more than twice rated, will not occur in any winding. Twice the rated voltage shall be applied across a winding at approximately twice the normal frequency, or in a manner that will not exceed twice rated current.

Examination During and After Test

Magnetic components, undergoing the tests, shall show no internal corona or arcing during the test. After the test, the magnetic component shall be examined for evidence of arcing, flashover, breakdown of insulation, and damage. Visible damage or detection of voltage breakdown or corona, by insulation, shall be cause for rejection.

High Voltage Test Equipment

Corona Detection Network

Detection of corona or arcing shall be by a current, or series type network, as shown in Figure 10-19. Insert the Corona Detection Network in series with the ground, or return of the high voltage circuit being tested. Indicators, LB-1, and LB-2, shown in Figure 10-19, serve the dual purpose of corona and arc indication, and over voltage protection. Inductance L1 and L2 are in series and provide a significant ac impedance, from audio frequencies to nearly 0.5 MHz respectively, which is the significant frequency range of corona voltage. The function of the capacitor, C1, is to attenuate the ac supply frequency to a sufficient degree, but pass the corona burst pulses, so the maximum sensitivity of the oscilloscope may be utilized. The power supply waveform, appearing on the oscilloscope, shall serve as a reference for corona bursts, as shown in Figure 10-20. Thus corona bursts can be distinguished from extraneous noise in the circuit.

Vacuum Chamber

The vacuum equipment shall have sufficient capacity to pump down to the critical region in 20 minutes with the chamber air and outgassing loads present.

Switching

Switching of the magnetic component, high voltage leads shall be accomplished externally to the vacuum system.

Oscilloscope

The frequency response of the vertical amplifiers of the oscilloscope shall be flat to 1.0 MHz. Deflection sensitivity of the trace shall be 10 millivolts/cm or less. The zero trace of the oscilloscope shall be blanked out visually by opaque tape, so that the intensity can be turned up sufficiently to see the trace.

Quality Assurance

Introduction

Pursuing reliability in the manufacturing of transformers and inductors primarily involves attention to details, coupled with close controls in all phases of manufacturing. The manufacturing cycle should be controlled and monitored by a conscientious Quality Assurance (QA) program, which includes appropriate in-process inspection points, and testing activities to prevent workmanship defects and assures delivery of a high reliable end product.

Quality Assurance Requirements

Assumptions Prior to Fabrication

Vendor Survey

A vendor survey had been performed and all open items had been closed.

Facility and Work Stations

Facility (Clean Room)

The general assembly and soldering area shall have a controlled environment, which limits the entry of contaminations. The temperature and humidity in the soldering area shall be monitored and maintained within the comfort zone, as shown in Figure 10-23. The enclosed soldering facility will maintain a positive pressure, unless the soldering area is not in an air-conditioned, clean room.

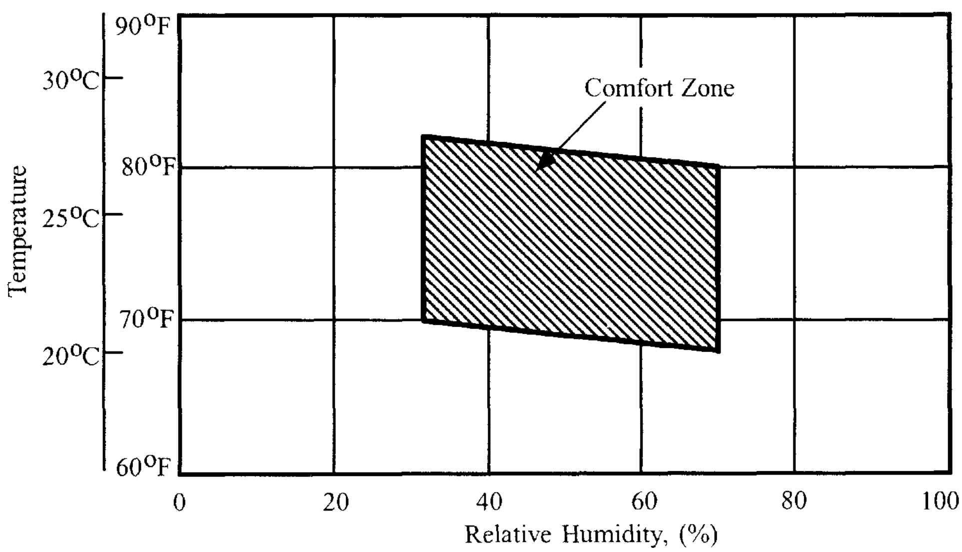


Figure 10-23. Temperature and Humidity in the Soldering Area.

Lighting

The lighting at the working surface for soldering and solder pot operations shall have a minimum illumination of 100 foot-candles.

Handling Parts

Prior to handling parts and/or materials, the operator shall thoroughly clean his/her hands; the use of any hand lotion is forbidden. Anyone working or handling parts and/or materials must wear clean gloves and/or finger cots. Gloves must be changed when they show signs of contamination, and finger cots must be replaced when they are torn or contaminated.

Work Area

The work areas and workbenches shall be maintained in a clean and orderly manner. At the start of each workday, the work stations shall be free of visible dirt, grime, grease, flux or solder splatters, and other foreign materials.

Restrictions

There will be no smoking, eating, or drinking permitted at the work stations.

Cosmetics

Hand cream, ointments, perfumes, cosmetics, and other materials unessential to the fabrication operation shall not be permitted at the work station.

ESD Protection Requirement

Supplier shall establish and maintain a documented program for the control of Elect-Static Discharge, (ESD), during fabrication and handling of such devices. The program shall comply with the requirements of MIL-STD- 1686.

Certified Personnel

All certified personnel must have up-to-date, valid training certificates before fabrication can begin.

In-House Fabrication Procedures

All fabrication drawings and procedures must be signed off by the cognizant engineer before work can begin. There shall no red line drawings in the magnetic component assembly area.

Purchase Order

The purchase order or contract has to be issued between the company and vendor, before any parts are ordered or the beginning of fabrication. The purchase order, or contract, defines the test that will be performed, the manufacturing, and the quality assurance requirements.

Fabrication Review

A fabrication review will have been conducted between the company and the vendor to assure that the vendor is ready to begin fabrication and testing.

Engineering Model (EM) or Prototype

After the engineering model, (EM), has been tested for form, fit, and function, a review panel that will involve the vendor and the Company Quality Assurance, and the cognizant engineer will be setup to access the magnetic component for practicality, reliability, and fabrication.

Before the Start of Fabrication

Procedures

Quality Assurance personnel shall review, inspect, and give their concurrence on: (a) assembly drawings, (b) test procedures, (c) potting procedures, (d) inspections, (travelers), and (e) shipping.

Materials

Quality Assurance personnel shall review, inspect, and issue a Part Acceptance Tag (PAT tag), as shown in Figure 10-24, on all materials such as: (a) wire, both magnet and insulated, (b) insulation material, (c) magnetic cores, (d) enclosures, (e) terminals, and (f) solder type.

Equipment

Quality Assurance personnel shall review, inspect, and give their concurrence on: (a) the winding machine, (b) the tension device, (c) the soldering iron, (d) the solder pot, (e) hand tools, and (f) aids.

Part Acceptance Tag No. 35002

Part Number	Revision	Lot Number
P.O./W.O. Number	Inspection Report No.	Cert. Number
Supplier	Quantity	Date Received
Cert. Number	Date Inspected	Inspection Stamp

Figure 10-24. Typical, Quality Assurance, Part Acceptance Tag.

Documentation

Materials Certification

Manufacturers of the materials shall supply certification of conformance for the required and applicable specification.

Traceability

100% traceability of all parts and materials shall be maintained throughout the process from the receiving, or source inspection, to the final tests.

Reverse-Traceability

The information content of each document shall be sufficient to provide reverse-traceability.

Manufacturing and Inspection Records

All manufacturing and inspection checks shall be recorded on an approved, (Traveler). See Figures 10-25 and 10-26. The approved fabrication instructions will accompany each deliverable item, which will provide an accurate history of the part.

Deliverable Package

A documentation package shall be maintained for each deliverable piece of electronic equipment, and will include approved fabrication instructions, inspection reports, deviation reports, and all Material Review Board, (MRB), evaluations. This package will also include a Certificate of Compliance, serialized test data, and the traceability information.

In-Process Inspection

In-Process Inspection

The Company Quality Assurance personnel shall set up mandatory in-process inspection points after the vendor supplies assembly and test flow charts.

Discrepancies

Any discrepancies, with respect to the specification, drawing or inspection standards, defined in the contract, shall be written up on an Inspection Report, (IR). The, (IR), will be submitted to the company, cognizant engineer for disposition. Parts, that have been written up on an Inspection Report, (IR), will be assessed for impact to form fit or function.

Common Problems

In the fabrication of magnetic components, the most common problems found over the years are: (a) cold solder joints, (b) nicked magnet wire, (c) magnet wire lead dressing, and (d) magnet wire lead fatigue.

Unit Specification Verification

Test Demonstration

Verification, by testing, is accomplished by subjecting the magnetic component to a set of conditions under the control of the approved test plan, procedures, and test equipment which will provide the accurate test data. The results of the test are compared with the specification control drawings.

Test Discrepancies

Any discrepancies in the test results, when compared to the specification requirements, shall be written up by the company Quality Assurance. This information will be submitted to the cognizant, company engineer for disposition. The parts will be assessed for impact to form fit or function.

Visual Inspection

The magnetic component shall be measured/inspected to verify that the construction, the physical dimensions, the correct markings, cleanliness, and the workmanship are in accordance with the specification, control drawings.

Traveler-Transformers, Inductors and Coil Assemblies (Front)

Assembly No. ______________________ Program ______________________

Drawing No. & Rev. ______________________ Machine ______________________

Serial No. ______________________ Specification No. ______________________

Material Core	Part Number	IR/PAT	Type	Tech	Date	QA	Date
Bobbin / Tube							
Wire Hook Up							
Tape Adhesive							
Tape Cloth Poly							
Shielding							
Banding Strap							
Seal Strap							
Air Gap Material Mylar							
Housing							
Terminal Board							
Sleeving							
Remarks							

Figure 10-25. Typical, Transformer, Inductor Inspection Traveler Card, (Front).

Traveler-Transformers, Inductors and Coil Assemblies (Back)								
Winding Number	Wire AWG	Turns	IR/PAT	*Test	Tech.	Date	QA	Date
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Inspection Prior to Soldering								
Solder Wires and Inspect								
Electrical Test								
Encapsulation								
Marking __________	Serial No. ____________							
Assembly No. ______	Part No. ______________							
*Test to Perform	A. Magnetizing Current			B. Turns Ratio		C. See Winding Specification		

Figure 10-26. Typical, Transformer, Inductor Inspection Traveler Card, (Rear).