

AT Series Testers

**Application Note** 

# Ferrite Transformer Testing



### Introduction:

Voltech

As electronic products utilise higher frequency techniques to reduce size and improve efficiency, ferrite cores are used in an increasing proportion of transformer designs. Transformer manufacturers must therefore meet a need for smaller transformers designed to operate at higher frequencies, which introduces additional demands on both manufacturing and testing methods.

These issues apply to a wide range of common applications including switched mode power supplies, lighting ballasts, inverter drives, audio and telecommunications equipment and many more. 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. In the following pages, we will consider the range of tests that are appropriate for thorough testing of ferrite transformer designs and we begin with a review of the components present in a common transformer.

#### FIGURE 1

Pri Pin 1 Sec Pin 1 Leakage Inductance Primarv Resistanc Secondary Resistance Core e Losses n Primarv Inductance Pri Pin 2 Sec Pin 2 AT series Inter-winding capacitance power and sense nodes

Schematic of a simple two winding transformer connected to the four wire Kelvin nodes of an AT series transformer tester.

From the schematic in figure 1, it can be seen that even the most simple of transformers includes quite a complex combination of resistive and reactive components. In order to establish with confidence that a transformer has been manufactured correctly, it is necessary to execute a range of tests that combine to provide an assurance that the materials used and manufacturing process executed results in transformers that meet the design specification.

**CTY:** Continuity.

Voltech

Ensures that the transformer is correctly seated in its fixture and that all winding termination integrity is good.

Unit of measurement, Ohms. Range from  $10K\Omega$  to  $10M\Omega$ .

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.

R: Resistance.

Ensures that the gauge of copper being used for each winding is correct.

Unit of measurement, Ohms. Range  $10\mu\Omega$  to  $10M\Omega$ .

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

Figure 2 Example test entry screen for resistance using the Editor program.

	Schematic			Maximize		Available Tests	Minimiz
	PRI1	<u>~</u>	SEC1		CTY R	Continuity Winding Resistance	
	PRI2	کے اچ	<mark>⊕</mark> SEC2		LS LP L2	Inductance (Series Circu Inductance (Parallel Circ Inductance Match	- 52
		ξ	⊕ SEC3		LSB LPB	Inductance with Bias (Se Inductance with Bias (Pa	0.0000000000000000000000000000000000000
	SCRN1 CORE1	<u>`</u>	Integration Short C Medium Terminals High Terminal Low T PRI1 PRI2	erminal			-
1.	Continuity Maximum Continuity Resistance: 10		Resistance Limits				
2.	Winding Resistance Integration: Short High Terminal: PRI1 Minimum Value: 4.0000 Ohms	Low Max	C% C≻ Minimum C> C< Maximum [		_	hm C Ohm C kOhm C hm C Ohm C kOhm C	
3.	Winding Resistance		ОК Ме	asure	Ca	ancel Voltec	<b>b</b>

# VOLTECH NOTES

LS: Series inductance.

Ensures the correct core material has been used and that the number of turns is correct.

Unit of measurement, Henries. Range 1nH to 1MH with signal level from 1mV to 5V @ 20Hz to 3MHz

Different core materials exhibit different permeability and therefore a different value of inductance for a particular number of turns. With the correct number of turns, inductance provides a measure of the core materials ability to maintain the required magnetic flux without saturation.

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<u>Part Sohematic Program Tester Server Setup Ha</u>	elp				
Schematic		Maximize	Ą	vailable Tests	Minimize
PRI1 PRI2	SEC1		R	Continuity Winding Resistance	<u>×</u>
			LP	Inductance (Series Circuit) Inductance (Parallel Circuit) Inductance Match	
SCRN1	Frequency 30 Terminals High Terminal Low PRI1 <b>P</b> RI3	⊙mV C \ C Hz ⊙ k Terminal		Integration Short C Med	dium
Minimum Value: 300.00 m0hms 5. Inductance (Series Circuit) Test Voltage: 100.00 mV Test Frequency: 30.000 kHz Integration: Short High Terminal: PRI1 Nominal Value: 173.00 mH Minimum Error: -10.00%	Inductance Limits			el <b>Volte</b> c	
For Help, press F1	💽 Inbox - Microsoft Out 🗐 104-	128-0-54.doc -	🏼 🖉 Part		NUM / //

Figure 3 Example test entry screen for inductance using the Editor program.

#### QL: Quality Factor

Voltech

Ensures that core material and its assembly is correct

Unit of measurement, Q. Range 0.001 to 1000 with signal level from 1mV to 5V @ 20Hz to 3MHz

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

#### Figure 4 Example test entry screen for Q Factor using the Editor program.

🛎 Part :- SC FERRITE DEMD, File :- SC FERR		Program Editor			_ 🗆 🗵
Part Schematic Program Tester Server Setup	Help				
C C C C C C C C C C C C C C C C C C C		Maximize		A THE TON	Minimize
		Maximize	ZB	Available Tests Impedance with Bias	Minimize
PRI1	SEC1		- (14)		_
PRI2	کې SEC2		QL D	Q Factor D Factor	
			RLS	Equivalent Series Resist	ance
	5		RLP Z	Equivalent Parallel Resis	tance
	SEC3		2	Winding Impedance	×
	Test Parameters				
SCRN1	Signal [100	J (• mV	CV (	C mA C Short C	Medium
, in the second s	Frequency 30	C Hz	🖲 kHz 🛛	C MHz C Long	
CORE1 o					
	Terminals				
Program List	High Terminal	Low Terminal	-		
Nominal Value: 173.00 mH	PRI1 💆	PRI2			
Minimum Error: -10.00%	Maximu - O Factor Limits-				
6. Q factor	0% 0 ×	Minimum 7			
Test Voltage: 100.00 mV		ronomismi Tr			
Test Frequency: 30.000 kHz Integration: Short	⊙> C <				
High Terminal: PRI1	Low Te				
Minimum Value: 7.0000	OK	Measure		Cancel	ltech 🗾
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		1			

**ANGL:** Angle of impedance.

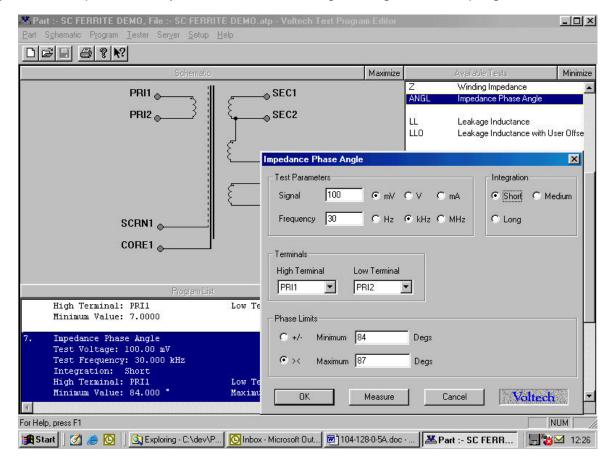
Voltech

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

Unit of measurement, Degrees. Range -360° to +360° with a signal level from 1mV to 5V @ 20Hz to 3MHz

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

Figure 5 Example test entry screen for Phase Angle using the Editor program.



#### LL: Leakage inductance

Voltech

Ensures that windings are positioned correctly on the bobbin and that any air gap included in the core design is the correct size.

Unit of measurement, Henries. Range 1nH to 1kH with signal level from 1mV to 5V @ 20Hz to 3MHz

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. The AT series testers eliminate these problems with a unique measurement technique that is described in detail in a separate technical note VPN: 104-105.

Figure 6 Example test entry screen for leakage inductance using the Editor program.

Schematic			Maximize	Ava	ailable Tests	Minimi
PRI1 PRI2		-∲ SEC1			akage Inductance	
			©uA O OHz ⊙	mA OmV kHz OMHz	Integration Short C C Long	Medium
SCRN1 CORE1		Primary Terminals High Terminal Low Te PRI1 I PRI2 Secondary Terminals	<b>.</b>	Additional Low * Available CORE1 SCRN1	Terminals Used SEC2 SEC4 SEC5	A
Program List Leakage Inductance Test Current: 600.00 uA Test Frequency: 30.000 kHz Integration: Short Terminals: Primary High: PRI1 Secondary High: SEC1 Additional Low Terminals: SEC2, Maximum Inductance: 90.000 uH	Prij Seco SEC4,	High Terminal Low Te SEC1 SEC3 Leakage Inductance Limits C % C >< C > • < Maxim	rminal	Add->	CmH CmH	

C: Inter-winding capacitance

Voltech

Ensures that the insulation thickness between windings is correct.

Unit of measurement, Farads. Range 100fF to 1mF with signal level from 1mV to 5V @ 20Hz to 3MHz

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

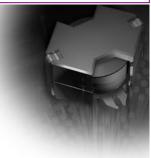
Figure 7 Example test entry screen for capacitance using the Editor program.

₩Part - SC FERRITE DEMO, File - SC FERRITE DEMO.atp	- Voltech Test Program Editor			_ 🗆 🗵
Part Schematic Program Tester Server Setup Help				
Schematic	Maximize	e Availa	ble Tests	Minimize
PBI2	SEC1		vinding Capacitance citance Match	
	<u> </u>	V C V Iz @ kHz C MHz	Set Limits	dium
SCRN1 CORE1 Program List	High Terminals Available Used PRI1 SEC1 SEC2 SEC3 SCRN1	Low Termina Available PRI1 PRI2 CORE1 SCRN1	Used Used SEC4 SEC5	A
Maximum Inductance: 90.000 uH 9. Interwinding Capacitance Test Voltage: 50.000 mV Test Frequency: 30.000 kHz Integration: Medium High Terminals : SEC1, SEC2, SEC3 Low Terminals : SEC4, SEC5 Minimum Capacitance: 10.000 nF Maximum	Add ->     <- Remov	C pF	<ul> <li>Remove</li> <li>nF C uF</li> <li>nF C uF</li> </ul>	
For Help, press F1	OK Measur	e Cancel	Volter	<b>h</b>
For Help, press FI	ficrosoft Out	∝	: FERR   🔙 🐮	✓ 12:30

### TR: Turns ratio.

Voltech

Ensures that the number of turns on each winding and the winding polarity meet specification.



Unit of measurement, Decimal Ratio. 1:100k to 100k:1 with a signal level from 1mV to 5V @ 20Hz to 3MHz

Turns ratio is measured to establish that the number of turns on primary and secondary windings are 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 figure 1 will result in a voltage ratio that does not correspond exactly with the ratio of physical turns present on the windings. The AT series testers include the ability to calculate turns from the ratio of inductance (TRL) which overcomes errors attributable to core loss and leakage inductance. This and other turn ratio considerations are described in a separate technical note VPN: 104-113.

Figure 8 Example test entry screen for Turns Ratio using the Editor program.

Schemati	2	Maximize	Available Tests	Minim
	SEC1		R Turns Ratio	
rniz <sub>@</sub>	Turns Ratio Test Parameters Voltage 100 • mV O Frequency 30 • Hz •	V kHz O MH;	Integration C Short C Medi C Long	um
SCRN1 <sub>©</sub> CORE1 <sub>©</sub>	Energised Terminals High Terminal Low Terminal PRI1 PRI2	] Se	condary Terminals	
Program L Test Frequency: 30.000 kHz Integration: Short Terminals: Energised High: PRI1 Primary High: PRI1 Secondary High: SEC1 Turns Ratio: 550:100 Minimum Error: -05.00%	High Terminal     Low Terminal       PRI1     PRI2       Ratio Limits       © %       Primary : Secondary       550       C #       Neg       5     %		ch Terminal Low Termina C1 SEC2 Polarity 0 +ve % No Test	· ·ve

# VOLTECH NOTES

**SURG:** High voltage surge testing (AT3600 only).

Ensures 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.

Unit of measurement, mV Seconds. Range 1mVs to 1kVs with an impulse signal level from 100V to 5kV.

Transformers with a high number of turns using fine wire are vulnerable to insulation damage. 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 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 within the AT3600 to a transformer winding, the winding is exposed to an impulse voltage and by measuring the area under the decaying oscillation, it is possible to establish if a breakdown between turns of the winding has occurred. The diagram below illustrates the decaying oscillation of a transformer winding with no insulation damage versus the same winding with damaged insulation.

Figure 9 Surge waveform examples

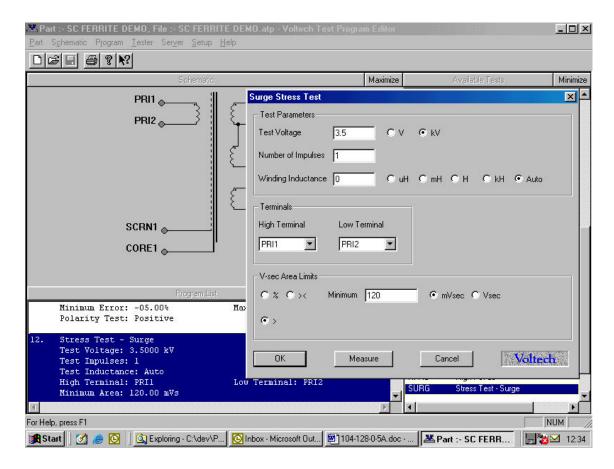
Good component - 150mVSec

Bad component - 75mVSec

By computing the volt-second product under the curve, the AT3600 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.



Figure 10 Example test entry screen for Surge Stress using the Editor program.



**IR** Insulation Resistance.

Voltech

Ensures that the isolation between windings meets the required specification

Unit of measurement, Ohms. Range  $1M\Omega$  to  $100G\Omega$  with a signal level from 100V to 7kV (AT3600) or 500V (ATi).

Using a DC high voltage generator and DC current measurement system, the value of resistance is calculated.

Figure 11 Example test entry screen for Insulation Resistance using the Editor program.

🛎 Part :- SC FERRITE DEMO, File :- SC FERRITE D	EMO.atp - Voltech Test Program Editor	
Part Schematic Program Tester Server Setup Help		
Schematic	Maximize Avai	lable Tests Minimize
PRI1	Insulation Resistance	<u>▲</u> ×
PRI2	Test Parameters Integration	
	Voltage 1 C V O kV O Short	C Medium C Long
لے ا	Note: ATi and AT1600 max is 500V	S medium S Long
Ι		
	Available Used Available	Used
5	PRI1 SEC1 PRI1	SEC4
	PRI2 SEC2 PRI2 CORE1 SEC3 PRI2 CORE1	SEC5
SCRN1	SCRN1 SCRN1	
CORE1		<b>Y</b>
	Add -> <- Remove Add ->	K-Remove
Program List	Insulation Resistance Limit	
Minimum Area: 120.00 mVs	Minimum Resistance 50 © MOhms © G	iOhms
13. Insulation Resistance	Note: ATi and AT1600 maximum resistance limit is 10 GOhn	a
Test Voltage: 1.0000 kV		
Integration: Medium Terminals:	OK Measure Cance	Voltech
High Terminals: SEC1, SEC2, SEC3		akage Current
Low Terminals: SEC4, SEC5 Minimum Resistance: 50.000 MOhms		ulation Resistance
T		
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# VOLTECH NOTES

HPAC High Voltage AC safety testing (AT3600 Only).

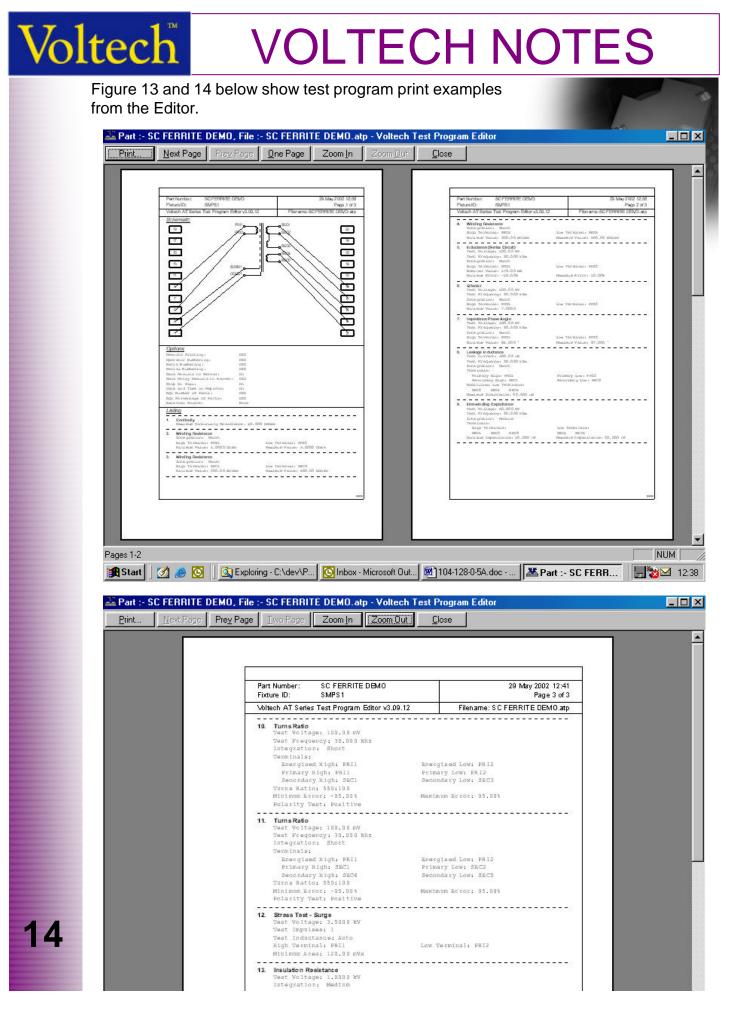
Ensures that the windings are positioned correctly with the correct materials to provide the required level of safety isolation.

Unit of measurement, Amps. Range 10uA to 10mA with a signal level from 100Vac to 5kVac.

All transformers that provide isolation from an AC power system must be tested to confirm their ability to withstand safety-testing voltages without breakdown. In order to meet testing regulations, it is necessary to provide evidence that the test voltage is maintained during the test period and the AT3600 achieves this by measuring and controlling the applied voltage throughout the complete duration of test.

- 0 × Schematic Program Tester Server Setup Help Maximize Minimize × 🔺 High-Pot AC PRI1 Lest Parameters PRI2 C V · kV Ramp-Up Time 0.1 Voltage sec 60 Hz **Dwell Time** Frequency sec High Terminals Low Terminals Available Used Available Used CORE1 CORE1 4 4 SEC1 SCRN1 PRI2 SCRN1 SEC2 SCRN1 SEC3 SECA SEC5 CORE1 Ψ. v Add -> <- Remove Add -> <- Remove Test Limit otential A Maximum Current 5 mA (Peak) Test Voltage: 4.0000 kV Test Frequency: 60.000 Hz mp Up Time: 100.00 ms Voltech Dwell Time: 2.0000 s ОK Cancel High Terminals : PRI1, PRI2 Low Terminals : SEC1, SEC2, SEC3, SEC4, SEC5 HPA( High-Pot ac Maximum Current: 5.0000 mA SUBG Stress Test - Surge For Help, press F1 NUM 🛛 🔯 Exploring - C:\dev\P... 🔯 Inbox - Microsoft Out... 👼 104-128-0-54.doc - ... 🌌 Part :- SC FERB... 🋃 Start 🛛 🏹 ಿ 💽 - 237

Figure 12 Example test entry screen for HPAC using the Editor program.



# VOLTECH NOTES

Figures 15 and 16 below show batch statistics from the Server software.

ATI	Part Name	Operator			Batch				
1157	FERRITE-DEMO								
Last Part	Pass	Tested			3	Transformer Serial No.			
PASS	1	FAIL	0			AQL	i.	AQL	None
<b>RE-TRIES</b>	0	% FAIL	0.000			Last	10 Tx	0 Fai	led
Test	Min	Мах			Last Result	FAILS	Pola	rity	PolFAILS
1 CTY 2 R 3 R 4 R	150.00 mOhm	10.000 250.00 150.00 30.000	mOhm mOhm		198.31 mOhm 197.93 mOhm 93.962 mOhm 4.9463 mOhm	0 0 0 0			
5 LS 6 LL 7 C	7.2200 uH 300.00 nH	7.9800 500.00 150.00	uH nH		7.5634 uH 404.50 nH 98.397 pF	0 0 0			
8 QL 9 ANGL 10 TR 11 TR	8.0000 88.000 ° 826.50 m 6.6500	90.000 913.50 7.3500	m		10.640 89.314 ° 875.12 m 6.9791	0 0 0 0	+ +		0
12 IR	10.000 MOhm	7.5500			4.6477 GOhm	0	· <b>T</b> ·		U

### **Conclusions:**

It can be seen that the appropriate range of tests will provide complete assurance that all materials and production processes within a transformer are correct. This in turn will guarantee that each and every transformer tested is known to fully meet the required specification. Such thorough testing here has historically been to costly, too difficult or too time consuming. However the AT series testers provide a cost effective, easy to use and fast solution. The complete test shown above was executed by the ATi tester at a speed of 1.2 seconds, with the single touch of a button.

# VOLTECH NOTES

### AT Series Testers



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