Inductance Impulse Tester

IPT1000 （1000A）

IPT1500 （1500A）

Shenzhen Zhiyong Electronics Co., Ltd.

Safety Requirement

The DC impulse voltage will be up to 400V on output port, testing cable, clip and EUT of this device during operation. Please carefully read the following safety instruction and follow related safety precautions.

- **Only the cable with safety plug and clip with insulation protection provided by original company can be used as testing cable and clip.**
- **Platform used for testing must have insulated surface to prevent high voltage leakage.**
- During the testing, the display interface will show the following warning sign as shown below. **Do not touch any cable or clip** when this sign is up. Only connect or disconnect cable and clip when the sign disappears.

- **Do not dismantle and repair** the device on your own, please contact us to solve any irregular phenomenon.
- Only well-trained technician should be allowed to operate the device, and it should be managed under specially assigned staff.

1. Preface

The current measurement we used on inductor usually applies LCR bridge. Through auto balancing theory of the bridge, an digitized bridge measures parameters of the inductor (including inductance and quality factor etc.) by applying a high frequency voltage signal on inductor under test. As the AC voltage used for measurement is less than 10V, the current through inductor is also lower than tens mA, and the bridge will measure the inductance parameter under this small signal. This method is usually applied on measurement of inductor component in a small signal analog circuit.

The inductor is known to be a non-linear component, and the current through the inductor would decide the magnetization of the magnetic material in the inductor, and thus establish relationship between inductance value and current. The current LCR bridge + DC bias source measuring method is achieved by overlaying a high frequency small signal on a stable DC current. This traditional method is not only expensive but also complicate to operate, meanwhile it's maximum current is limited to 200A, which is way behind the development of today's power electronics products.

With the rapid development of the large power electronics and new energy product, the current rating of power inductor rises day by day, and requirement for power inductor more than 1500A is no longer a news. The engineers today concern for a series of questions: whether the inductance attenuation of the power inductor can fulfill design requirement under high current? Is it saturated and to what extent? These questions are crucial for designing a product aiming for high reliability and low cost.

2. IPT1000/IPT1500

- Measure the incremental inductance and secant inductance.
- Fast and easy measurement.
- Wide measurement range that is able to cover inductors from 0.1A to 1500A.

3. Measurement theory

The basic theory of $\frac{di}{dt}$method is to apply constant DC impulse voltage to the inductor and calculate the corresponding parameter like inductance through measuring the $\frac{di}{dt}$ change of the inductor. Formula is shown below.

$$U=L\frac{di}{dt}$$

The diagram shown below is the flux linkage to current curve of the inductor. When the current reached the preset maximum current IB, test ended. Secant inductance L_{sec} and incremental inductance L_{inc} will change corresponsively according to the change of operating point A on magnetization curve with change of current.

We define the incremental inductance (dynamic inductance or small signal inductance) as L_{inc}

$$L_{inc}=\frac{\Delta\Psi_{mA}}{\Delta I_A}$$

The physical meaning of the incremental inductance is actually the same as the inductance we gained by normal LCR meter.

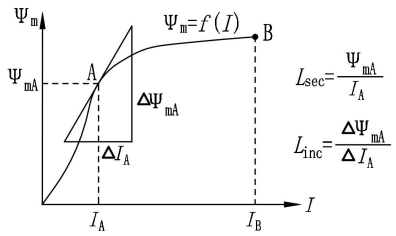
IPT1000/1500 calculate incremental inductance for a sect of DC magnetization curve. LCR meter + DC BIAS Unit method is measuring incremental inductance by accumulating a small AC Hysteresis loop on DC

magnetization curve.

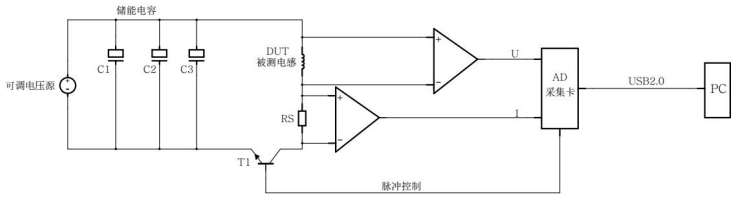
Accumulating an AC magnetization curve on a DC bias current is exactly how filter inductor work in power electronics field. Incremental inductance is the key users concern for.

And Secant inductance or large signal inductance L_{sec} is defined as below, which cannot be measured by LCR meter.

$$L_{\text{sec}} = \frac{\Psi_{\text{mA}}}{I_A}$$



Secant inductance L_{sec} and Incremental inductance L_{inc}



IPT 1000 basic theory diagram

Comparing to DC bias unit method, IPT1000/1500 has outstanding advantages:

- Because of the single pulse measurement, large bias current can be produced by discharging the inductor up to thousands ampere.
- Because the measurement condition is in accordance with the operating condition of square wave pulse voltage in inductance component, IPT1000/1500 will generate result much more similar to the actual operating power electronics.

4. Accessories

Choosing the proper clip and connecting cable is crucial for inductance measurement. For different measurement requirement in different situation, IPT1000/1500 has three different sets of clips and connecting cables.

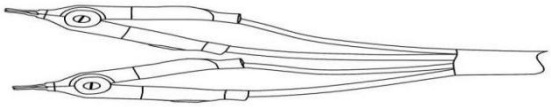
4.1 Connecting Cable

- **CK-307A:** Double end large current plug cable (Around 2m) used for pulse current measurement on 1000A/1500A gear.

Attention: Non-banana plug contains auto-lock structure. When plugged into the large current gear of the device, push the plug until your hear a click. When unplugging, push the plug to the bottom and then pull it out, or the plug lock will prevent you from doing so.

- **CK-308:** Double end banana plug cable (Around 2m) used for voltage or pulse current below 1500A.

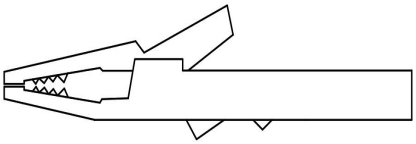
- **CK-309:** Double end banana plug with kelvin clip cable (around 1m) used for inductance measurement of pulse current lower than 100A. Please note that: thick cable should be connected to the current connector and thin cable should be connected to the voltage connector.



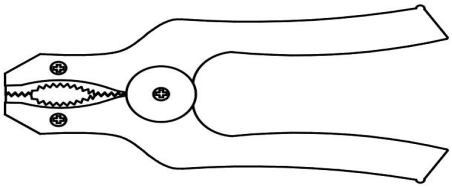

4.2 Clip

CK-261: Used for voltage or current measurement within 100A.

CK-263： Used for pulse current measurement within 1000A.



CK-264： Large current kelvin clamp used for pulse current measurement within 1500A. Every clamp has two banana sockets, and a pair of black and red clamp form a whole kelvin clamp.



5. How to use IPT1000/1500

Please carefully read the following safety instruction before actual operation.

- **The device will generate DC pulse voltage up to 400V on output port, test cable, clamp and component under test. Please strictly follow the safety precautions.**
- **Only the cable with safety plug and clamp with insulation protection provided by original company can be used as testing cable and clamp.**
- **The platform used for testing must contain insulated surface to prevent high voltage leakage.**

1) Connecting PC

First of all, connect IPT1000/1500 to PC through the USB connector, turn on the machine through the switch on front panel, the “Power” LED will be lighted, blinking for 2 to 3 sec, and display the operation preparation status. After that, start the IPT1000/1500 program on PC, and the device will be ready soon. If you don’t have the program, please refer to the instruction manual and install software on PC.

2) Test clamp and operating method

Kelvin Four-terminal sensing

The standard four-terminal sensing uses a pair of current cables to supply the large pulse current to the inductor under test and measure the voltage on the inductor by another pair of cables. The voltage measuring cables need to be connected to the VOLTAGE PROBE socket in the middle of the front panel, and the current cable need to be connected to one of the three sets of current output sockets on the left according to the current selected.

Test Connection Diagram

The diagram above shows the correct four-terminal sensing method. The cable and clips used in the diagram above is CK-308, CK-263 (for current) and CK-261 (for voltage). The clips for voltage and current must be isolated from each other on the lead of inductor under test. The current clips need to have good contact with the lead, or the large pulse current will generate sparks.

Do not connect the clips for voltage and current together, this will increase the contact resistance of the clips and worsen the accuracy.

The correct four-terminal method set the clips as shown above, on different sides of the inductor under test. The electromagnetic coupling between cables is weakest in this layout and provide best measuring accuracy. Do not put the cables and clips on same side, or accuracy cannot be guaranteed.

You can simplify the layout with our CK-264 large current kelvin measuring clamp. Put them on different side of the inductor under test and proceed with measuring.

There are two banana plugs on each clamp, corresponding to voltage and current cables. A pair of R&B clamps forms a complete kelvin test clamp as shown below:

3) Operating the measurement program

3.1 Select the measurement parameter

IPT1000/1500 provide two different operation modes:

- Voltage will be applied on test component under preset current level is reached. (The measurement impulse will be ended when current surpasses the limit). This is the normal operation mode.

- Apply the voltage onto test component until reach the preset time limit. (preset “voltage time integral”)

After activated the software, the following parameter must be set before measurement.

✧ **Maximum Current**

Make sure your maximum current is within the range test component connected to, or you must change the port.

There are three ranges available.

	Range 1	Range 2	Range 3
Current Range	1～10A	11～100A	101～1000/1500A

✧ **Measurement Voltage**

Input the value corresponding to the voltage level of the test component. The voltage on test component can be adjusted ranging from 10V to 400V.

Because of the measurement theory, the voltage under measurement must be higher than actual operation voltage. For instance, when measuring a 24 VDC electromagnet, you should select 40-60V for range. The measurement theory always requires enough voltage drop at the inductor of impedance, or the current transfer ratio $\frac{di}{dt}$ will converge to zero, unable to evaluate.

✧ **Measurement Time (Maximum duration of measurement impulse.)**

When reaching this value, the measurement impulse will be stopped as long as the maximum current level is not reached. A useful setup that can be related to the transformer or the inductor’s voltage time integral. The maximum duration of the measurement impulse can be preset ranging from 100μs to 70ms when needed. Maximum limit is 70ms.

3.2 Measurement

✧ **Start Measurement**

- Press the command button <Start Measurement> to begin.
- Select <Resistance> option to measure resistance only.
- Select <Inductance + Resistance> button to measure resistance and inductance together.

The resistance range for these two selections should be within 3Ω, if the resistance of the inductor is over 3Ω, only <Inductance> single option should be selected, and type in the resistance value on your own. (by using other device ahead).

During the testing, the display interface will show the following warning sign as shown below. Do not touch any cable or clamp when this sign is up. Only connect or disconnect cable and clamp when the sign disappears.

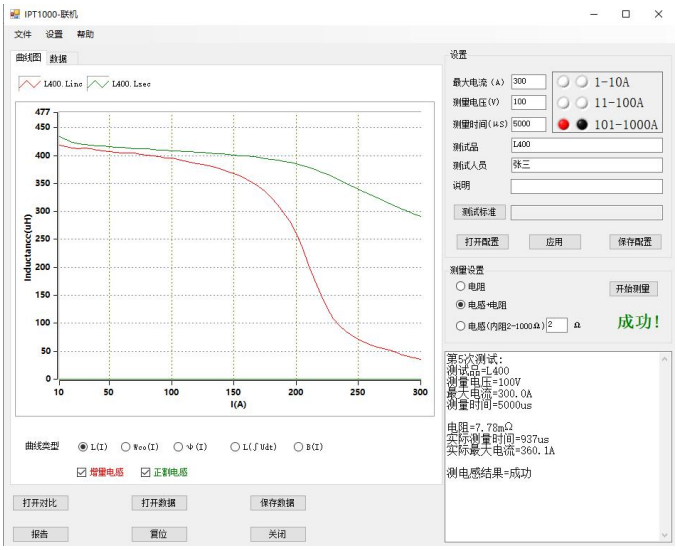
✧ **Status display**

- The software interface will display the current executing operation, please keep an eye on it.
- There’ll be detailed warning tip when the device is used incorrectly. (Including wrong connection or wrong parameter)

✧ **Measurement Diagram**

Select one of the parameter L[I], L[∫Udt], ψ[I] or Wco[I] to display measurement result diagram.

Below the measurement diagram, the curve will be displayed in the form of {current/inductance} and corresponding {time voltage integral/ inductance}. The results of every small current ahead of range may be inaccurate and thus will probably not be displayed.



Main Interface

➢ Inductance L[I]

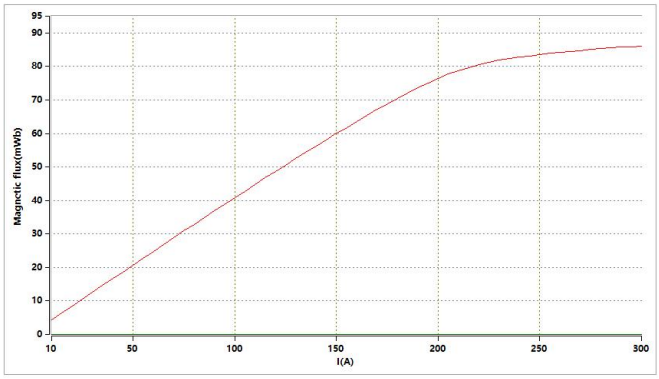
Normally will display the L[I] diagram, which is the function that will display inductance L as current I.

Selecting incremental inductance and secant inductance, these two curves can be displayed. Definition can be found in appendix of this manual.

➢ Inductance L[∫Udt]

In some cases, the voltage time integral function ∫U（t）dt applying inductance to the test component will be useful.

➢ Flux Linkage ψ[I]

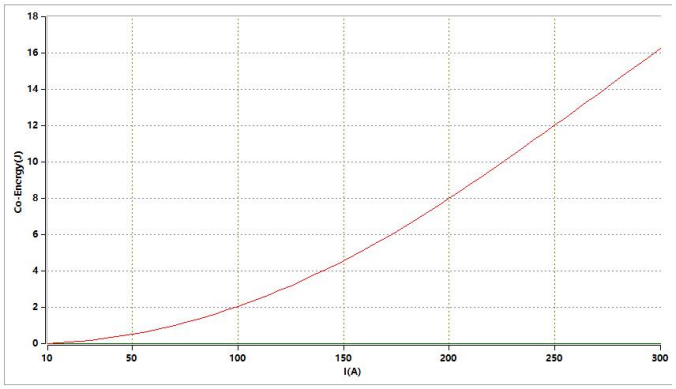


Flux Linkage Diagram

The Flux Linkage is in direct proportion to the voltage time integral of the device under test. If the number of turns and the cross section of the iron core is known, the flux density can be determined through flux linkage.

➢ Magnetic Co-energy Wco（i）

The magnetic co-energy Wco(i) corresponds to the integral of the flux linkage ψ(i) with respect to current, as a function of current. It can be helpful for the design, for instance, reluctance motors.



Magnetic Co-energy Diagram

✧ Other supportive function introduction

➢ Loading and Saving Measuring Parameter

Click the “save configuration” button on the upper right corner of the main interface to save the measurement parameter used on certain equipment under test. (This will not save the data collected.) Click the “load configuration” button to apply the saved measurement parameter. You can save the name of the EUT, name and annotation of the measurement device (if limit curve is requested)

➢ Saving and Loading measurement parameter and result

There’re two methods to save and load measurement parameter and result:

① Click “save data”button on the lower left corner of the main interface to save the measurement parameter and result of certain EUT. Click “load data” to load the saved measurement parameter and result.

② Use the “files\save” from the menu to save corresponding data.

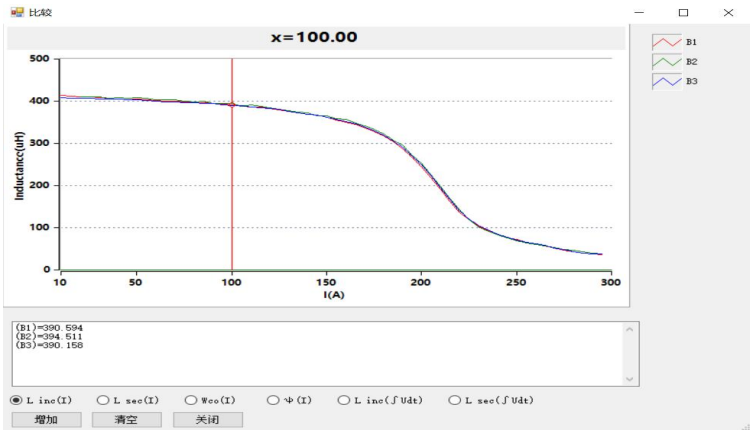
The file is saved with suffix “.ipt”with these two methods.

➢ Comparing multiple inductance curves

There’re two methods to compare multiple inductance curves:

① Click the “start comparison” button on the lower left corner of the main interface to load a saved curve and compare it with the latest curve.

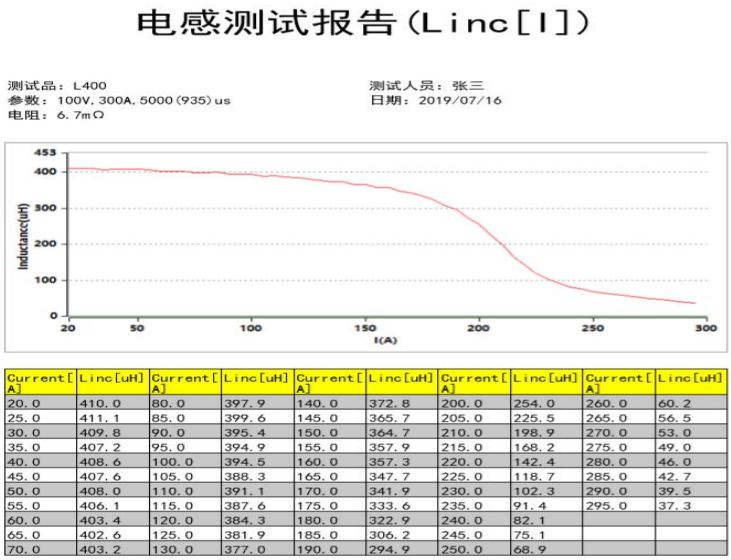
② Click the “set\compare” on the menu to load multiple saved data and compare them. You can empty the curve from the diagram.



Comparing multiple inductance curves

➢ Generate Report

Click the command button “report” to create test report in PDF form. It will include measurement diagram, data form, measurement parameter and comments.



Current[A]	Linc[uH]	Current[A]	Linc[uH]	Current[A]	Linc[uH]	Current[A]	Linc[uH]	Current[A]	Linc[uH]
20.0	410.0	80.0	397.9	140.0	372.8	200.0	254.0	260.0	60.2
25.0	411.1	85.0	399.6	145.0	365.7	205.0	225.5	265.0	56.5
30.0	409.8	90.0	395.4	150.0	364.7	210.0	198.9	270.0	53.0
35.0	407.2	95.0	394.9	155.0	357.9	215.0	168.2	275.0	49.0
40.0	408.6	100.0	394.5	160.0	357.3	220.0	142.4	280.0	46.0
45.0	407.6	105.0	388.3	165.0	347.7	225.0	118.7	285.0	42.7
50.0	408.0	110.0	391.1	170.0	341.9	230.0	102.3	290.0	39.5
55.0	406.1	115.0	387.6	175.0	333.6	235.0	91.4	295.0	37.3
60.0	403.4	120.0	384.3	180.0	322.9	240.0	82.1		
65.0	402.6	125.0	381.9	185.0	306.2	245.0	75.1		
70.0	403.2	130.0	377.0	190.0	294.9	250.0	68.9		

➢ Software version number

Click “help\about” on the menu to display the firmware version of the program and serial number of the device.

Precautions

This device contains shortage protection and further safety related self-inspection function. If the shortage protection is triggered or the self-inspection fails, the LED (power) on the front panel will blink, and the device need to be restarted before next operation. If the malfunction happened again after restart, the device must be sent to manufacturer for further check.

This device is designed for indoor environment temperature ranging from 0 ℃ to 50℃ and pollution level of 1. If the device has to be used in damp or condensation environment, there must be a 2-hour adaptive phase before usage.

☞ **If there’s any irregular phenomenon, please do not try to dismantle and repair on your own. Please contact our company.**

☞ **This device must be operated by trained technician and managed by specially assigned staff.**

6. Technical Specification

AC input voltage：	220V±10%	Measurable inner impedance：	0Ω～3000mΩ
Output voltage：	10V～400V	Maximum output energy：	1360 J
Output current：	1A ～10A	Basic inductance measurement accuracy：	±3%
(3 Range optional)	11A～100A	Communication Connector：	USB2.0
	101A～1000/1500A	Dimensions：	420(W)*360(L)*210(H) mm

Resistance testing accuracy: 0-300m Ω (± 0.5%+1m Ω)　300mΩ～3000mΩ (±0.5%+8mΩ)

Pulse setup time：	20us～70ms	Weight：	9.3 KG

Operating Temperature：0～50℃

Supplementary instruction about the data accuracy:

1.To reach specified accuracy, the following condition need to be met:

a)Inductance value>10 μH

b)Actual pulse time>10μs

c) Correct kelvin four-terminal sensing method

d)Good contact between clip and inductance under test with low contact resistance.

2.During the actual measurement, the accuracy cannot be guaranteed in part of curve that has current value lower than (0.08*maximum current value) because of the oscillations in the initial position of the current.

We advice you to put minimum measurement point that has current over (0.1*maximum current value) while designing measurement standard for better data.

7. Packing List

Packing List			
IPT1000/1500	1		
Power supply cable (CK-318)	1	R&B alligator clip (CK-263)	1
USB cable (CK-315)	1	Kelvin R&B clamp (CK-264)	1
R&B connecting cable (CK-307A)	1	USB flash disk	1
R&B connecting cable (CK-308)	2	Instruction manual	1
Kelvin test leads (CK-309)	1	Test report	1
R&B alligator clip (CK-261)	2		

Attachment 1: Installing Software

- System requirements:

Operating system: Windows 7 (32-bit, 64 bit) or Windows 10 (32-bit, 64 bit)

Recommended display resolution: 800 × 600 or greater

- Install software:

Please execute the file Setup.exe and follow the instructions. After installing the software, it will be necessary to restart the computer.

- Update instructions:

Before installing a new version, the old version of the software must be uninstalled through the control panel. Afterwards, you can install the new version as described earlier.

- All data, settings, and configurations will be saved in the “Documents\Cybertek\IPT”directory.

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