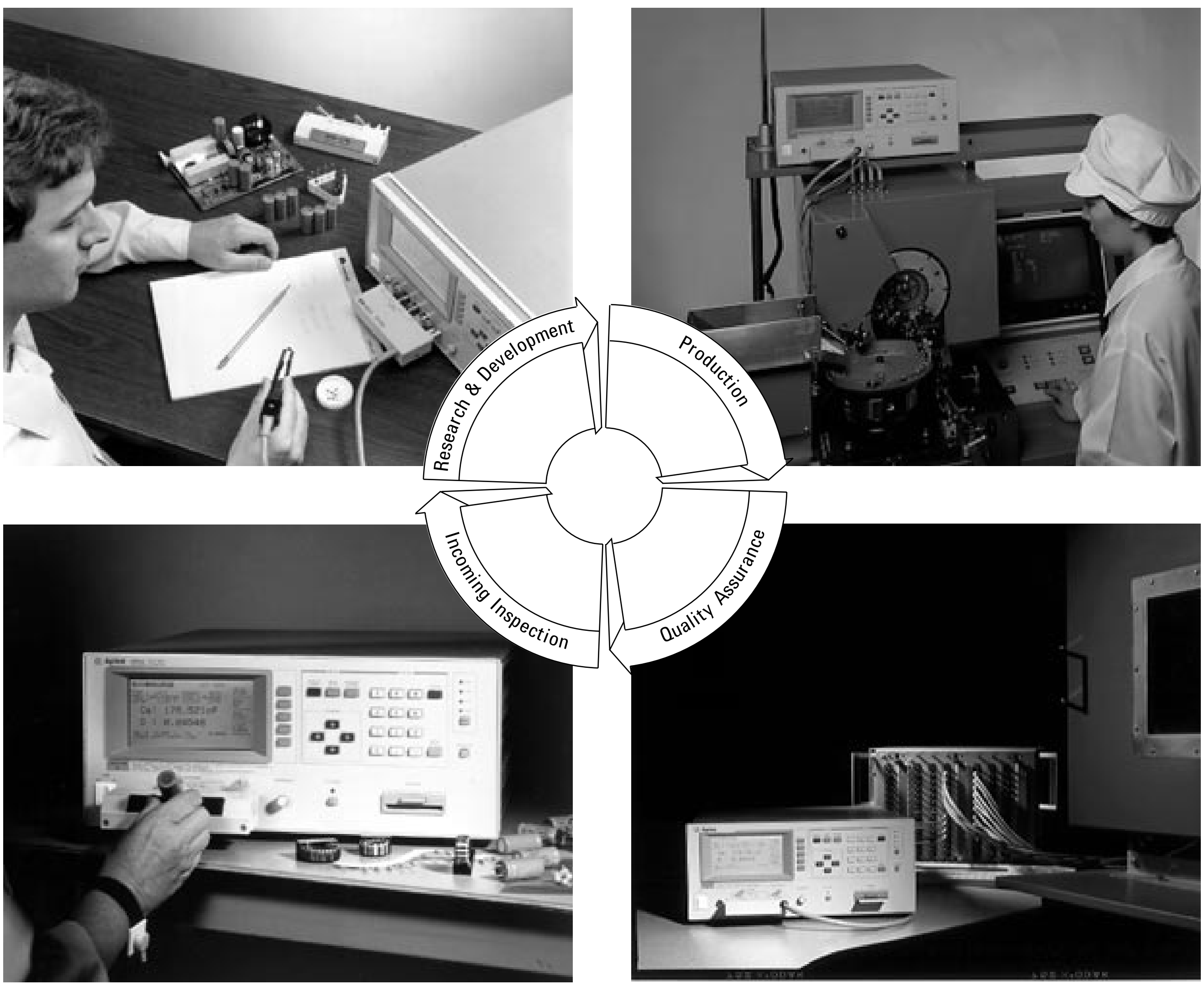
Agilent AN 369-1

Optimizing Electronic Component and Material Impedance Measurements

Application Note

Taking Full Advantage of the Agilent 4284A Precision LCR Meter's Versatility



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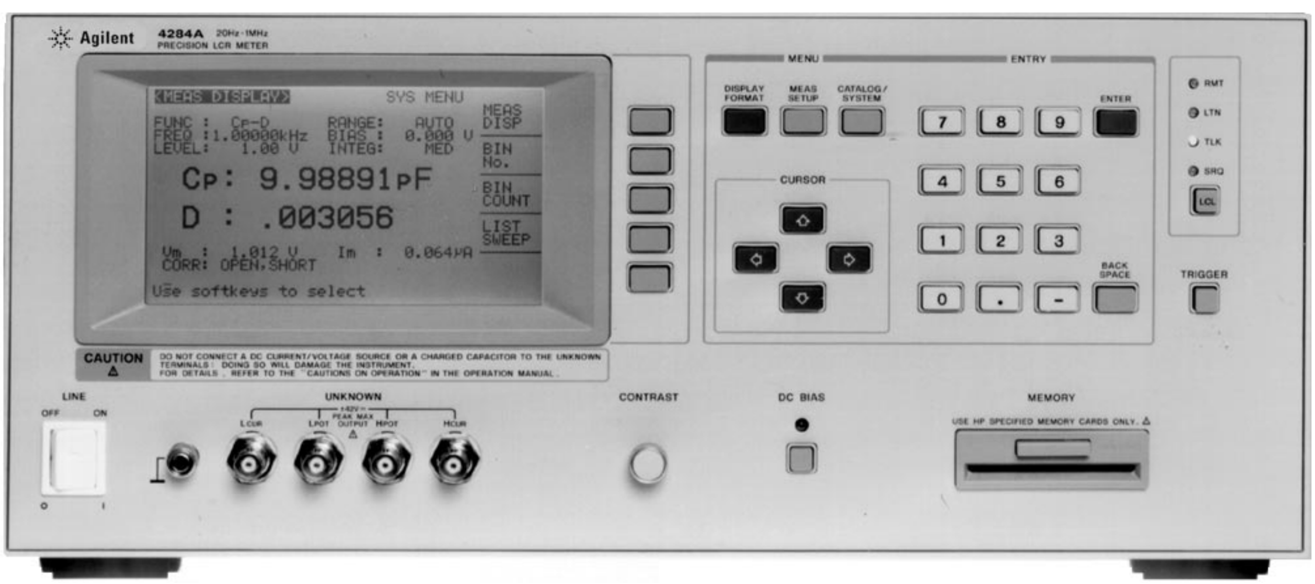

Introduction

Impedance measurements are a basic means of evaluating materials and electronic components that support the technical innovations of electronic instruments and equipment. Impedance characteristics of the components used in circuits or of materials vary with frequency, signal level, or the signal combined DC-bias voltage. For an engineer engaged in circuit design or component development, precise evaluation of impedance under the actual operating conditions is the first step towards obtaining high quality circuit design, and for the development and manufacture of high-performance components.

This application note describes the evaluation of electronic components and materials that will give full play to the wide range of frequency, signal levels, and DC bias settings.

Agilent 4284A Precision LCR, Meter

Sophisticated Measuring Functions that Meet the Demands for High Quality

The 4284A precision LCR meter provides highly accurate and efficient impedance measurement of electronic components and materials which enables it to give excellent cost/data performance. With a wide 20 Hz to 1 MHz frequency range and a reliable basic accuracy of 0.05%, it answers the measurement needs of testing high quality components. Attach option 001 and you get a maximum test signal level of 20 Vrms/200 mArms and a ±40 V DC bias which allows it to meet the measurement conditions that ensure fast and highly reliable evaluation of electronic components and materials characteristics. In addition, a constant-voltage/constant-current function maintains the test signal at a constant level to guarantee measurements are well within JIS and MIL standards.

Low-Cost and Highly Efficient Measurements in Any Measurement Environment

The outstanding basic functions of the 4284A and the wealth of available Options and accessories that extend these functions depending on the measurement objective, answer all of the measurement needs of research laboratories, screening inspection, quality control, incoming inspections, etc. You can easily create an automatic test system with options such as the GPIB bus interface, which includes buffer memory as standard, a handler interface, and a scanner interface. The ergonomic design of the front panel and the large easy-to-read backlit Liquid Crystal Display make it possible to take in measurement conditions and results at a glance. All measurement conditions can easily be set up using the display cursor, the arrow keys, and the softkeys. Furthermore, measurement setups can be recorded on a memory card to raise efficiency and to prevent mistakes. Thus, the efficiency of all stages of measurement, from measurement setup through data collection and analysis have been improved while costs have been lowered.

Key Specifications

4284A Precision LCR Meter

Test Frequency	20 Hz to 1 MHz 8610 points
Number of Digits	6 digits
Measurement parameters	|Z|,R,X: 0.01mΩ to 99.9999MΩ |Y|,G,B: 0.01nS to 99.9999S C: 0.01fF to 9.99999F L: 0.01nH to 99.9999kH D: 0.000001 to 9.99999 Q: 0.01 to 99999.9
Basic accuracy	|Z|,C and L: 0.05% D:0.0005
Test Signal Level Range	Voltage: 5mVrms to 2Vrms Current: 50µArms to 20mArms
Constant Test Signal Level Range	Voltage: 10mVrms to 1Vrms Current: 100µArms to 10mArms
Measurement Time	40ms/190ms/830ms at 1kHz
Test Cable Length	0,1, 2, and 4 meters (2 and 4 meters are option)
Comparator Function	Primary Parameter: 10 bins Secondary Parameter: HIGH/IN/LOW
Internal DC bias	1.5V and 2V

4284A Option 001

Test signal Level Range	Voltage:5mVrms to 20Vrms Current: 50µArms to 200mArms
Constant Test Signal Level Range	Voltage: 10mVrms to IOVrms Current: 100µArms to 100mArms
Internal DC bias	±40V with 0.1% accuracy

The Versatility of the Agilent 4284A

Research and Development of New Materials and Low Loss Electronic Components

Conventional LCR meters do not have the accuracy nor the resolution required for measuring the new low-loss electronic components and materials resulting from the latest materials technology. The 4284A has a basic accuracy of C: 0.05%, D: 0.0005, and a 0.000001 D resolution which allows it to measure high quality electronic components and materials. The 6-digit resolution of the display means that even minor changes in temperature and humidity characteristics are not missed. The powerful open/short/load error correction capability reduces measurement errors to a minimum.

Quality Assurance of Materials and Electronic Components and Incoming Inspection

For quality assurance and incoming inspection, measurements on the two frequency points, 1 kHz and 1 MHz are essential to meet AS and MIL standards. Since no previous LCR meter could cover both standard frequency points, two meters had to be used. The 4284A covers these frequency points with its wide measurement frequency range of 20 Hz to 1 MHz. Consequently, it covers all the principal standard frequencies required for quality assurance and incoming inspection, thus reducing the purchasing costs of measurement equipment and reducing maintenance costs. Furthermore, when measuring impedance frequency characteristics, no discontinuity of data is caused by instrument error. A powerful load compensation function has been added in addition to the conventional open/short compensation function to perform total error compensation.

Thus, even if the measurement values of the vendor differ from those of the customer due to instrument error, it can be canceled out by using the load compensation function and a working standard.

Evaluating the High Frequency Characteristics of Switching Power Supplies

The power supply is an extremely important part of any electronic instrument. The ever increasing sophistication of electronic components and their miniaturization have led to a demand for power sources that are equally compact and low cost. The switching power supply, the immediate answer to this demand, has become quite common. The recent advances in materials and circuit technology have led to a trend to raise the switching frequency. However, raising the operating frequency also causes a rise in the loss characteristics of the components used, and the parasitics in the components used cannot be ignored. This makes it important to evaluate the impedance of the components used at the actual operating frequency. The 4284A, by virtue of its capacitance and dissipation factor accuracy of 0.05% and 0.0005, respectively, up to 1 MHz, makes a vital contribution to high reliability design.

Evaluating Test signal/DC-Bias Dependency of Ferroelectric Materials

The working life of a switching power supply is often shortened due to the aluminum electrolytic capacitors electrolytic drying up. The increase in switching frequency has led to employ of small value capacitors, and to the switching over to other types of high reliability capacitors. High dielectric constant ceramic capacitors are regarded as particularly promising. The capacitance of these capacitors varies greatly with the AC/DC voltage applied to them, and with temperature changes. This effect increases as the dielectric constant of the capacitor's dielectric material increases and with increasing values of capacitance. For this reason, due care has to be paid in the design stage. When these capacitors are used as filter capacitors in the input and output of a switching power supply, the effective capacitance may be lower than the design value causing an increase in output noise. When the load becomes inductive in character, the transient response deteriorates. Thus, capacitors must be evaluated under actual operating conditions. However, conventional LCR meters had the following limitations when used for this type of measurement:

- An External Circuit (Power Amplifier) is required.
- The measurement accuracy cannot be foretold.
- The current of the test signal cannot be increased and high values of capacitance cannot be measured at high frequencies.

The DC Bias Sources were also Limited.

- Only spot bias built-in.
- Only an external bias terminal was supplied and an external computer, and an GPIB controlled power supply were required.

An Agilent 4284A equipped with Option 001 can make measurements at up to 1 MHz and at signal levels of up to 20 Vrms /200 mArms, and can apply a DC bias of up to ±40 V. Since no external circuits are needed, and calibrations can be performed with the options installed, measurement efficiency and accuracy are not sacrificed. The full 6-digit display resolution makes it possible to monitor even minimal temperature and humidity changes. All 4284A functions can be controlled by GPIB; the DC bias can be set with a high accuracy of 0.1% which makes the 4284A ideal for multi-frequency C-V measurements.

The Physical Properties of Liquid Crystal Materials

Due to its compact size and low power consumption, Liquid Crystal Displays are used in pocket TVs, wordprocessors, computers, etc., and new applications are appearing all the time. LCDs are now used in a wide variety of applications and manufacturers must blend different types of liquid crystal materials to obtain the required characteristics, and these mixtures must be critically tested to determine whether or not they meet the required characteristics. The voltage level of the test signal of conventional LCR meters was not adequate, as a measurement voltage several times greater than the threshold voltage (1.2 V - 3 V for TN LCDs) could not be applied. This made it necessary to use the complicated curve fitting methods to derive an experimental value, or to use an external circuit to amplify the test signal.

The 4284A equipped with Option 001 can make measurements over a frequency range of 20 Hz to 1 MHz at a test signal voltage of 5 mVrms to 20 Vrms. This makes it possible to simplify measurement methods by using approximation calculations based on the linear relationship between the test signal voltage and the high voltage capacitance characteristics. An external circuit is not required, and since calibration can be performed with the options installed, measurements can be made without sacrificing efficiency and accuracy.

Constant-Current Evaluations of Magnetic Materials, Coils, and Magnetic Heads

In order to raise the Q of magnetic core coils and magnetic heads, magnetic materials with a high relative permeability are used. The magnetic, temperature, and humidity properties of a core are greatly influenced by the use of core materials which have high relative permeability. Consequently, the impedance value varies with the strength of the test signal and with the strength of the DC bias current. This is the reason why a constant magnetic field is used to evaluate magnetic core coils, and magnetic heads. Since the strength of the magnetic field is proportional to the current and to the number of turns in the coil, it is possible to make a constant current measurement as long as the number of turns in the coil is held constant. However, conventional LCRs have the following limitations.

- Only a spot voltage can be selected as the constant-voltage signal source.
- The measurement voltage is not GPIB bus controllable.
- The measurement current cannot be monitored.

For the above reasons, constant-current measurements are either impossible, or a computer must be used for control; this requires longer setup time and is not a practical solution. The Agilent 4284A has a built-in Automatic Level Control function (ALC) to facilitate constant-current measurements. The built-in microprocessor monitors the measurement current and uses this feedback information to control the test signal voltage. This means that efficiency is not sacrificed by having to transfer data to an external computer.

Higher Productivity in the Production of Electronic Instruments and Components

Improving productivity is an ongoing concern for manufacturers. On the production line, reducing the measurement time required is extremely important since it raises productivity and reduces costs. In research departments, the increasing number of measurements to be made and the ever larger number of materials to be measured make higher measurement speed and efficiency an absolute necessity. The dilemma with conventional LCR meters is that accurate measurements require longer measurement time, and if the measurement time is reduced, accuracy suffers. The 4284A offers the best solution to this dilemma in that it can make measurements up to 1 MHz in 30 ms measurement time in the short mode and with a basic accuracy of 0.1%. This is a vast improvement in efficiency and accuracy. The unique list sweep function allows the programming of a maximum of ten measurement points and having the result displayed in tabular form without the use of an external computer.

The 4284A can perform automatic screening inspections on the production line fast and accurately by installing Option 201 or 202 handler interface. Maximum measurement speed can be maintained at all times even when samples that cause internal short circuits are connected.

The following sections will give detailed measurement examples using the 4284A.

Evaluating the Level and Bias Dependency of High Dielectric Constant Ceramic Capacitors

Aluminum electrolytic capacitors were used in conventional power switching supplies as filter capacitors. However, the recent trend is to develop power switching supplies of ever higher frequencies to make them more compact, lighter, and cheaper. This trend has led to a demand for filter capacitors that are equally compact, and developers are beginning to look for other types of capacitors. In some power switching supplies, high capacitance multilayered ceramic capacitors are being used for their low ESR characteristics at high frequencies and their long life at high temperatures.

As shown in Figure 1 and Figure 2, when a DC bias voltage is applied to the high capacitance multi-layered ceramic capacitors which use high dielectric constant dielectrics, the capacitance varies with polarity. Since the ripple of the switching power supply increases with variations in filter capacitor's capacitance, the material must be tested under measurement conditions that are identical to the actual operating conditions. By installing

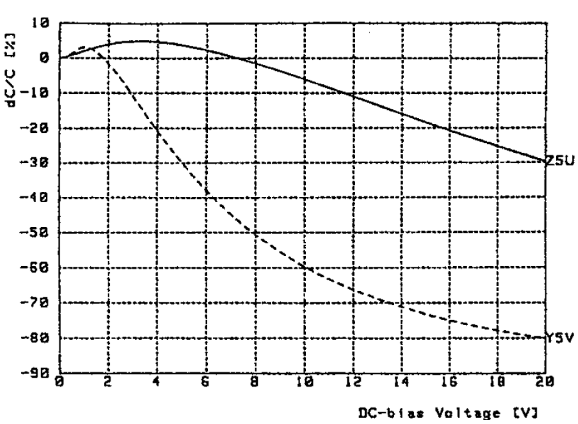

Figure 1. DC Bias Dependence of Capacitance

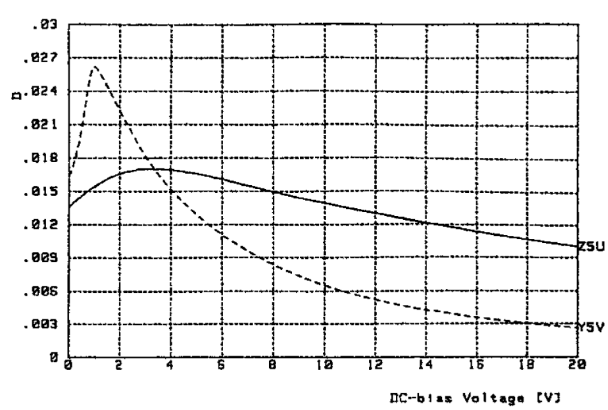

Figure 2. Loss Coefficient of DC Bias Dependence

Option 001 in the 4284A, test signal levels of 5 mV–20 Vrms, 50 µA–200 mArms and a DC bias of ±40 V can be used for measurement. Since no external circuits need to be employed and all required options can be calibrated when installed in the 4284A, all measurements can be performed without sacrificing accuracy and efficiency.

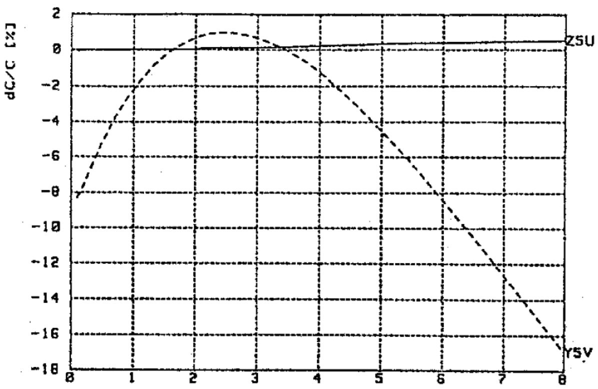

Figure 3. Signal Voltage Dependence of Capacitance

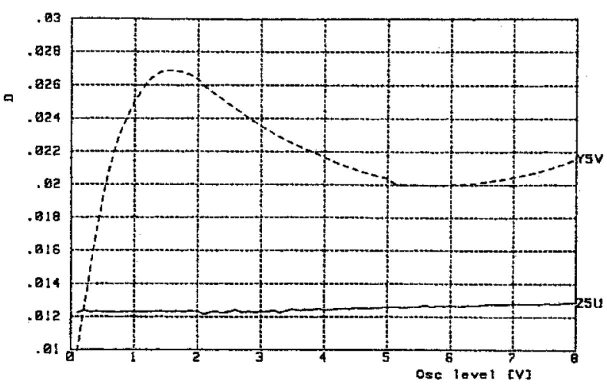

Figure 4. Signal Voltage Dependence of Loss Coefficient

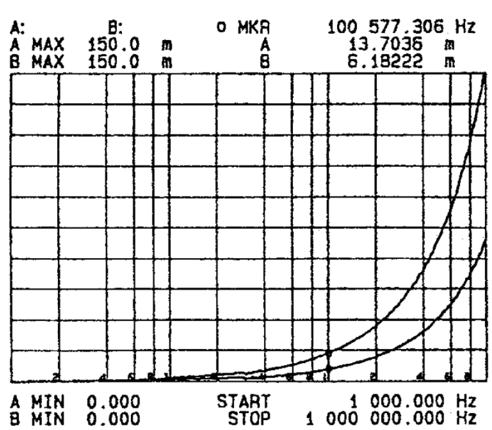

Figure 5. Frequency Characteristics of Loss coefficient of Film Capacitors (by the 4194A)

Thus, the 4284A will quickly perform all evaluations required in component design to improve the reliability and functions of switching power supplies, and help to make their development more efficient. When used with a scanner interface, the 4284A can also be used for environmental chamber testing.

Since the 4284A can store compensation data for a maximum of 128 channels, it is easy to build a reliable temperature and humidity test system.

Automation of Multi-Frequency Evaluations of Film Capacitors

Film capacitors, which are used in motors and power supplies to reduce noise, have to be highly reliable. The evaluation of the dissipation factor (D) is particularly valuable in preventing heat and fire in the capacitor due to ripple current. The following will describe making high speed and highly accurate measurements with the 4284A on the production line and in quality assurance departments.

Screening Tests of Film Capacitors

The capacitance of film capacitors are normally tested at 1 kHz, the JIS and MIL standard frequency. As shown in Figure 5, the D value increases as the frequency increases and it is therefore usual to perform tests at 10 kHz and 100 kHz. The 4284A does not only make high resolution C-D measurements at 1 kHz, but can make programmed measurements using the list sweep function at 1 kHz, 10 kHz, and 100kHz and perform these measurements in order automatically.

The 4284A can cover all the required measurement frequencies. Six full digits of resolution for all measurement parameters, and a maximum dissipation factor resolution of 0.000001 make the 4284A ideal for testing low-loss capacitors. The capacitance and dissipation factor accuracy are 0.05% and 0.0005 at 1 MHz, respectively, which will increase yield figures, and improve quality on the production line. The 4284A increases efficiency. It has an excellent built-in comparator which allows 10 bin sorting of C, and in/out tests of D or ESR. The handler interface option facilitates connection to automatic equipment. An extension cable of 4 m (Opt. 006) can be connected and the accuracy of measurements performed at the end of the cable are ensured.

Recently, automatic equipment with built-in scanners has been constructed with the aim of raising throughput. When the scanner interface is installed in the Agilent 4284A the combination can perform multi-channel compensation for a maximum of 128 channels. Since open/short/load compensation can be performed for each channel, errors can be reduced to a minimum to guarantee accurate measurements. The unique list sweep function of the 4284A allows you to program up to ten sweep points and to display in tabular form without using an external computer. Thus, it is possible to perform measurements at 1 kHz, 10 kHz, and 100 kHz in order, or to test the C limit value at 1 kHz and the D limit values at 10 kHz and 100 kHz. When the handler interface is installed, the test result at each point can be output.

Note:
The list sweep is performed at high speed so it is necessary to set an appropriate measurement delay time to allow for the sample response time.

```
<LIST SWEEP DISPLAY>          SYS MENU
  Film capacitor test
MODE : SEQ
 FREQ [ Hz ]   Cp [ F ]     D [    ]      CMP
  1 . 00000k   98 . 3941p   . 002396      H
  1 . 00000k   98 . 3941p   . 002396
  1 . 00000k   98 . 3941p   . 002396      L
  1 . 00000k   98 . 3941p   . 002396      L
  1 . 00000k   98 . 3941p   . 002396      L
  10 . 0000k   98 . 3413p   . 000650
  100 . 000k   98 . 3189p   . 000320
```

List Sweep Display Menu

The 4284A's memory card (Opt. 004) function can store entire measurement setups, including comparator limit information and list sweep table. This reduces the time required for production line setup and eliminates instrument setup errors. A turn-key system can be built so that a special setup is automatically loaded from the memory card when the power is turned on.

The capacitance and dissipation factor accuracy for the 4284A are 0.05% and 0.0005 at 1 MHz, respectively, which makes it ideal for quality control of low loss capacitors in quality assurance departments. A powerful load compensation function has been added, in addition to the open/short compensation function. It uses a working standard as a reference and makes sure that the measured value is compensated to yield an accurate measurement result under any measurement conditions.

```
<CORRECTION>                     SYS MENU
OPEN  : ON             CABLE : 0 m
SHORT : ON             MODE  : SINGLE
LOAD  : ON             CH No. : -----
                       FUNC  : Cp-D
FREQ1  : 1 . 00000kHz
  REF  A : 100 . 000pF        B : . 001700
  MEA  A : 98 . 4958pF        B : . 001736
FREQ2  : 1 . 00000kHz
  REF  A : 100 . 000pF        B : . 000300
  MEA  A : 98 . 2740pF        B : . 000547
FREQ3  : OFF
  REF  A : ------------       B : ------------
  MEA  A : ------------       B : ------------
```

Correction Menu

The comparator built into the 4284A can automatically perform bin counts up to 999999 and is a convenient feature when making sampling inspections. It can be programmed to emit a beep to announce when the limit test result is out.

```
<BIN COUNT DISPLAY>             SYS MENU
FUNC : Cp-D        NOM :   ------------- F
BIN    LOW [ F ]      HIGH[ F ]     COUNT
 1     +97 . 0000p    +98 . 0000p       0
 2                    +99 . 0000p       0
 3                    +100 . 000p     177
 4                    +101 . 000p     107
 5                    +102 . 000p       0
 6                    +103 . 000p       0
 7                    +104 . 000p       0
 8                    +105 . 000p       0
 9                    +106 . 000p       0
2nd    - . 000100     + . 005000    [    ]
REJ   CNT   AUX :  OFF    OUT :  0
```

Comparator BIN Count Menu

1. Option 006 2m/4m Cable Length Operation function must be used.

The menus, the measurement conditions which give the measurement results, and the measurement results can be printed out by a GPIB bus connected printer to facilitate the recording of necessary data. The 4284A's display cursor, arrow keys, and softkeys make it easy to check the measurement condition settings and measurement results. During sorting tests the operator can freely select the 'Normal measurement', 'BIN N0.' and 'BIN count' display page to suit the application. The memory card can store up to ten instrument setups, which the operator can choose by selecting a number on the catalog menu. This eliminates setup errors and simplifies operation.

```
<CATALOG>                    SYS MENU
MEDIA  :  CARD
No.  S              COMMENT
10   1   Power on auto exec setup
11   1   List sweep setup
12   1   Film capacitor test
13   1   Incoming inspection setup
14   0
15   0
16   0
17   0
18   0
19   0
```

Catalog menu

All these features make the 4284A precision LCR meter suitable for testing film capacitors.

Improving the Cored Coil Evaluation Method by Means of Constant-Current Measurement

The permeability of the magnetic material used in magnetic coils is not constant, but varies with the strength of the magnetic field, temperature, and other factors. When the current fed through a coil wound around a magnetic material is gradually increased, the magnetic flux density B changes as shown in Figure 6. Except at the origin, it is proportional to the strength of the magnetic field at the start, after which it steeply increases and then falls off. The saturation point is reached when all of the magnetic axes of the magnetic domains within the core material are aligned.

Consequently, the inductance of the coil also varies with the strength of the magnetic field. Thus, to determine the value of a magnetic cored coil, it has to be measured at a constant magnetic field level. That is, if the number of turns in the coil are held constant, a constant current can be used for the measurement.

$H = nI$ [AT/m] n = number of turns
I = current

Even though constant voltage signal sources were used in conventional LCR meters to set the signal source level to the same voltage and DC bias conditions, the measurement values varied from meter to meter. This was due to the fact that the output impedance of the signal source was different for different meters, and that the current flowing through the sample was also different. Table 1 shows an example.

Table 1. Differences in Measurement Values for Different Meters

Sample	Cored inductor: nominal value 2.2 mH	
Common measurement conditions	Frequency:1 kHz Signal Level:1 V DC bias:None	
Measurement Instrument	**Measured Inductance**	**Current Monitor Value**
4194A (50 Ω)	Ls: 2.30861 mH Q: 0.951	14.109 mArms
4284A (100 Ω)	Ls: 2.26907 mH Q : 0. 92	8.659 mArms

Current monitor value ( ) denotes output impedance of signal source

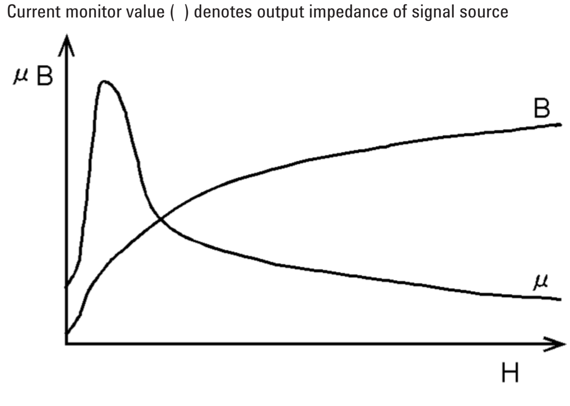

Figure 6. Magnetic Characteristics

For this reason, constant-current measurements with conventional LCR meters were achieved by using an external computer to monitor the signal source current, and to control the signal source voltage. Since data transfers had to be made via a GPIB bus, efficiency suffered and the need for an external computer raised system costs. Using the Agilent 4284A's built-in ALC[2] functions simplifies constant-current measurements. The built-in microprocessor controls the signal current and high efficiency is ensured.

In addition, the 4284A has a comparator function which is convenient for performing go/no-go production line testing. The handler interface makes it possible to connect the LCR meter to automatic equipment which is useful for performing automatic screening inspections of magnetic cored coils.

Evaluation of the Saturation Characteristics and Self-Resonant Frequencies of Magnetic Heads

Magnetic heads are used in audio, video, and in magnetic disk devices of digital equipment. High duality heads are required for analog applications, and high density heads are demanded in the digital field. A wide frequency range, core materials with high permeability, and high saturation magnetic flux density are required to produce high quality, high density magnetic heads. Raising the self resonant frequency of the coil is one way to widen its frequency range. This in turn makes it necessary to evaluate the self resonant frequency and other magnetic head characteristics during the development stage.

The following is a description of how the 4284A can be used in RED to evaluate magnetic heads.

The evaluation of heads for magnetic disks involves the following difficulties and demands.

- Since the characteristics vary with the strength of the magnetic field, the evaluation must be performed at constant magnetic field levels; that is, the head impedance should be measured using a constant current test signal.
- Impedance frequency characteristics are required when performing L-Q measurements at several frequencies to find the resonance point.
- A wider range of level characteristics at larger/smaller test signal currents, and higher frequency characteristics are now required.

Accurate Measurements are not Deteriorated by Test Fixture Influences

When conventional LCR meters were used for this type of measurement, a computer had to be connected to monitor the measurement current, and the measurement voltage level had to be adjusted for each measurement frequency. The measurement frequency and the test signal level had limitations that prevented the measurement under the desired conditions, which made a thorough evaluation impossible.

Evaluation of Multi-Frequency Characteristics using Constant Current

Even when the 4284A's measurement frequency is changed, it is still possible to make constant-current measurements across a wide current range of 100 µA to 100 mA[3]. The built-in ALC function has simplified constant-current measurements since it eliminates the need to adjust the test signal level every time the measurement conditions and the test devices are changed, as was the case with conventional LCR meters. Furthermore, with the measurement frequency range of 20 Hz to 1 MHz, and with 8610 settable measurement frequency points, the evaluation of frequency characteristics using the constant current measurement technique is easy. This means that the 4284A is capable of performing fast measurements of resonant frequency, which is essential for evaluating magnetic head characteristics. With the use of an external computer, data can be output to a computer via a GPIB interface for graphic representation to make it easier to determine the head characteristics and to promote development efficiency.

2. AUTOMATIC LEVEL CONTROL Function

Figure 7 shows the measurement results of the frequency characteristics of a floppy disk head by means of the constant current measurement technique.

Because test signal current level can be varied up to 200 mA[3], and the List Sweep function makes it possible to sweep a maximum of ten signal levels, the level characteristics of magnetic heads are easily obtained. A measurement example for determining magnetic head level characteristics is shown in Figure 8.

Highly Accurate and Highly Reliable Measurements

The 4284A is provided with open/short/load compensation functions; three powerful compensation functions which reduce the influence of test fixtures to a minimum. In addition, excellent repeatability guarantees accurate measurements even when the test fixture is changed to accommodate different types of magnetic heads. Thus the 4284A provides fast and easy constant-current measurements. As test signal levels can be set freely and list sweeps are possible, the 4284A is a single instrument solution for performing all of the measurements required to evaluate magnetic heads. This will improve the efficiency in developing and evaluating magnetic heads in R&D departments and raise reliability.

<LIST SWEEP DISPLAY> SYS MENU

MODE : SEQ

FREQ [Hz]	Z [ ]	0 [deg]	CMP
1 . 00000k	24 . 0580	4 . 850	
2 . 00000k	24 . 3196	9 . 638	
5 . 00000k	26 . 0770	22 . 974	
10 . 0000k	31 . 5171	40 . 189	
20 . 0000k	47 . 3697	59 . 156	
50 . 0000k	104 . 921	76 . 003	
100 . 000k	206 . 898	82 . 042	
200 . 000k	420 . 787	84 . 862	
500 . 000k	1 . 36758k	82 . 319	
1 . 00000M	11 . 8209k	- 30 . 352	

Figure 7. Constant Current Measurements of the |Z|-f Characteristics of Magnetic Heads

Conclusion

High accuracy impedance measurements are not the only requirement for the correct evaluation of electronic components. The following precise measurement condition setups are also important:

Measurement Frequency,
Test Signal Level: Voltage/Current, and
DC Bias: Voltage/Current

Only when these three measurement conditions are adjusted to meet the objective of the evaluation, and only when they are correctly set up will they make it possible to select components, to improve reliability, and to raise the quality of equipment design. The increased pace of precise measurements on the production line will raise the reliability of inspection. The 4284A Precision LCR Meter will raise the quality in development, in production, and in Quality Assurance for both component manufacturers and electronic equipment manufacturers.

<LIST SWEEP DISPLAY> SYS MENU

MODE : SEQ

LEVEL [A]	Ls [H]	Q [ ]	CMP
0 . 10m	323 . 833u	7 . 20	
0 . 20m	325 . 290u	7 . 14	
0 . 50m	328 . 300u	6 . 89	
1 . 00m	330 . 594u	6 . 71	
2 . 00m	330 . 333u	6 . 55	
5 . 00m	313 . 883u	6 . 11	
10 . 0m	286 . 463u	5 . 70	
20 . 0m	265 . 556u	5 . 46	
50 . 0m	219 . 635u	4 . 59	

Figure 8. Measurement Example of Magnetic Head Level Characteristics

3. When Option #001 is installed

Agilent Technologies' Test and Measurement Support, Services, and Assistance
Agilent Technologies aims to maximize the value you receive, while minimizing your risk and problems. We strive to ensure that you get the test and measurement capabilities you paid for and obtain the support you need. Our extensive support resources and services can help you choose the right Agilent products for your applications and apply them successfully. Every instrument and system we sell has a global warranty. Support is available for at least five years beyond the production life of the product. Two concepts underlie Agilent's overall support policy: "Our Promise" and "Your Advantage."

Our Promise
"Our Promise" means your Agilent test and measurement equipment will meet its advertised performance and functionality. When you are choosing new equipment, we will help you with product information, including realistic performance specifications and practical recommendations from experienced test engineers. When you use Agilent equipment, we can verify that it works properly, help with product operation, and provide basic measurement assistance for the use of specified capabilities, at no extra cost upon request. Many self-help tools are available.

Your Advantage
"Your Advantage" means that Agilent offers a wide range of additional expert test and measurement services, which you can purchase according to your unique technical and business needs. Solve problems efficiently and gain a competitive edge by contracting with us for calibration, extra-cost upgrades, out-of-warranty repairs, and on-site education and training, as well as design, system integration, project management, and other professional services. Experienced Agilent engineers and technicians worldwide can help you maximize your productivity, optimize the return on investment of your Agilent instruments and systems, and obtain dependable measurement accuracy for the life of those products.

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