

Beyond the Limits: 1296 Dielectric Interface

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One of the biggest challenges in dielectric measurement is the analysis of very high impedance, low loss materials such as ceramics. Accurate measurement of these parameters over a broad frequency range can yield valuable information about the properties of a wide variety of materials. In addition the study of frequency related phenomena as a function of applied bias or temperature is often essential in the laboratory testing of these materials.

Standard materials tests investigate the properties of a sample in terms of its ability to store charge (capacitance) and transfer charge (conductance). Analysing these parameters can provide valuable information in terms of molecular relaxation properties, and can be used to determine the curing nature of adhesives, grain boundaries, investigate phase changes, insulating properties, amongst other applications.

Applications

- Liquid Crystals (displays, high speed optical switching devices)
- Ceramics (high voltage applications, fuel cells)
- Epoxy Adhesives (used in airframe manufacture - composite materials)
- Electrical cable insulation materials
- Ferro / piezo electric materials (actuators for car suspension systems, engine valve controls, sonar, etc.)
- Composite materials studies, (porosity, grain boundaries, phase transitions)
- Electronic/carrier transport analysis of semiconductor and insulator materials
- Sensor development
- Printed circuit board development
- Non-linear electrical and optical effects
- Charge storage in conducting polymers

The discovery of new phenomena such as low-frequency dispersion (LFD), has led to the extension of investigations in the 10Hz to 10MHz range which Solartron has sought to address. The analysis of low frequency data is particularly important in situations where electronic or ionic carrier transport plays a significant role. Using analysis techniques in this frequency range information previously unobtainable can now be accurately determined.

Instrument requirements for useful analysis demands extremely accurate measurement of magnitude and phase, along with reference components and normalisation routines to minimise the effects of stray cell and lead capacitances. Solartron's 1260 Frequency Response Analyser is renowned for its accurate measurement of phase and its wide impedance range, but the development of modern materials has meant that further advances in measurement technology have been required. Solartron has been specifically designed the 1296 Dielectric Interface to extend the measurement capabilities of impedance analysers for the materials test market. The introduction of this dielectric test system now allows the user to investigate the frequency response of a material over an extended impedance range, and under varying experimental conditions of ac amplitude control, dc bias, and temperature.

The specification of the 1296 Dielectric Interface is achieved due to an exceptionally accurate current to voltage converter (1fA resolution) which allows the measurement of the ultra-low capacitance and current levels, which are commonly experienced in material/dielectric analysis. The combination of 1260/1296 and associated software gives:

- Impedance measurement range to >100Tohm
- Frequency range 10microHz to 10MHz
- Accurate phase / dielectric loss measurements using reference techniques:- Internal Reference, External Reference or Empty Cell
- High voltage tests up to 1kV AC and 1kV DC using external power supplies and amplifiers
- Temperature control using external controller (e.g. LakeShore 340) and cryostat (e.g. Oxford Instruments)

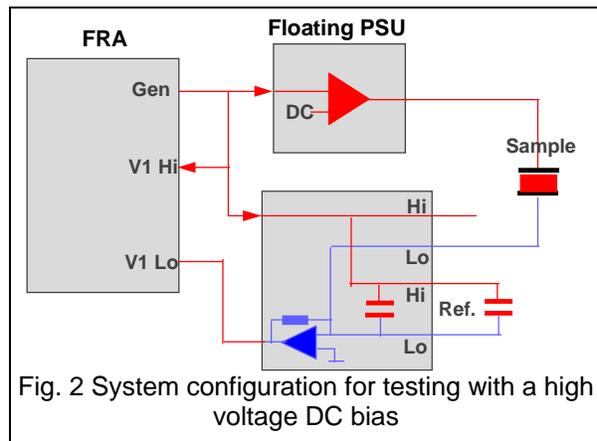
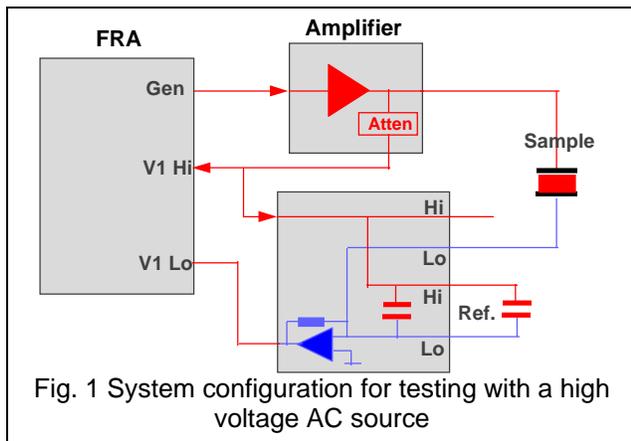
The system includes a set of highly accurate internal and external reference capacitors. During measurements made using the reference modes, two readings are obtained: one of the sample and one of the reference component of a comparable value. From a ratio of the two results the true sample value is calculated, removing any stray capacitances present at high frequencies. A software normalisation routine also enables the effects of lead and cell capacitance to be removed via a normalisation procedure.

The Dielectric Interface comes complete with its own fully integrated software package. It allows the user to study material characteristics in terms of relative permittivity, tan delta, modulus, capacitance, phase (deg., rad.), admittance, impedance, etc. Results can be displayed, or exported to the Zview package for further manipulation and equivalent circuit modelling, data can also be exported in CSV format to Excel. Support for temperature and dc controllers is also an integral part of the measurement software, which enables the range of investigations to be extended.

High Voltage Studies

There are many applications where high AC or DC voltages need to be applied to the material being tested (see Fig.1 and 2). It is often necessary to investigate the performance of materials close to their breakdown potential. Some electronic components are specified to operate over a wide voltage range (e.g. capacitors or transistors) and therefore must be tested under the same conditions. Piezo-electric and ferro-electric materials are operated at high voltage levels in order to maximise the response of these materials.

It is simple to integrate amplifiers and power supplies into the 1296 dielectric test system; the software has been designed to allow additional drivers to be added to the system for automatic control of these external devices.



Temperature Control Applications

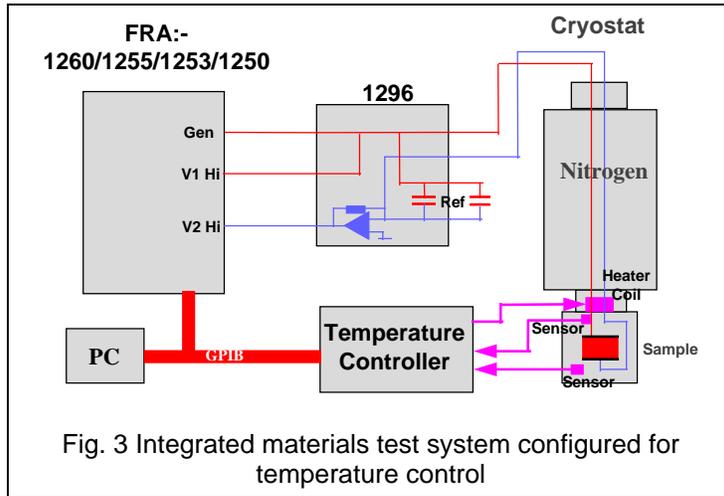
Many dielectric or high impedance materials need to be tested over a wide range of temperatures. Applications include testing fuel cell ceramic materials for use in satellites and space travel, assessing the reliability of LCD or other display materials, analysing the cure properties of adhesives or resins, and evaluating the performance of lubricants.

Changing the temperature of a material can bring high frequency relaxation responses into the frequency range of the impedance test equipment. The instrumentation can test over 12 decades of frequency, but with the addition of temperature control (see Fig. 3), this can be effectively extended to 16, by the principle of frequency-temperature superposition. This enables information taken at one temperature to be directly related to that at another, thereby increasing the range and reliability of the data.

From the 1296 software the temperature can be programmed at a fixed value or swept over a pre-defined range, via a temperature controller linked to a cryostat. The controller establishes the temperature in the

cryostat by applying a controlled current to a heater coil and monitoring the temperature via sensors. Low temperatures are achieved by using a cryostat filled with liquid nitrogen or helium and then using the heater coil to fight against the constant temperature of the coolant. The temperature range of the system depends solely on the cryostat and sensors which are being used.

The 1296 software includes a driver for the LakeShore 340 temperature controller, the driver routines are available to the user so that they may be modified to support other temperature controllers.



Summary

The development of the 1296 Dielectric Interface allows the user to extend the specification of Solartron analysers for materials testing, allowing extremely accurate measurement of capacitance, modulus, tan delta, Q factor, permittivity and other parameters. The system is particularly suitable for investigating LFD phenomena. In addition, the facility to control temperature, and apply ac/dc bias enables comprehensive materials characterisation. The measurement capabilities are further increased by the use of reference components and normalisation routines in the software, these functions minimise stray capacitances due to leads and cell configurations.

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