AN150310 Meeting the Challenges of Testing Filtered Connectors

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Abstract

Applied Relay Testing Ltd, England, specialises in the design of test equipment for a wide-range of passive components and electromechanical relay devices. With the emergence of filtered connectors it is of interest to create simple means for testing these multi-pin passive devices which often require precise measurement against demanding MIL specifications. To bring additional capability to the testing of these parts this paper outlines solutions for measuring filter connector capacitance at working voltage, reducing fixture measurement strays and a flexible software & hardware approach to programming the tests required.

Filtered Connectors.

Filtered connectors are increasingly important. The catastrophic effect of lightening induced energy pulses travelling along cable assemblies is well documented [1] and it would seem that the potential for these effects is likely to increase with the universal adoption of non-conductive lightweight composite materials for airframe construction. In addition, sensitive navigation and control systems are increasingly at risk from unwanted signals from mobile telephones and other close-by RF transmitters.

A filtered connector is a standard connector but with the addition of internal passive components to form a traditional ‘T’ or ‘Pi’ filter on one or more pins between one side of the connector and the other. There may also be protection devices such as varistors or zener diodes.

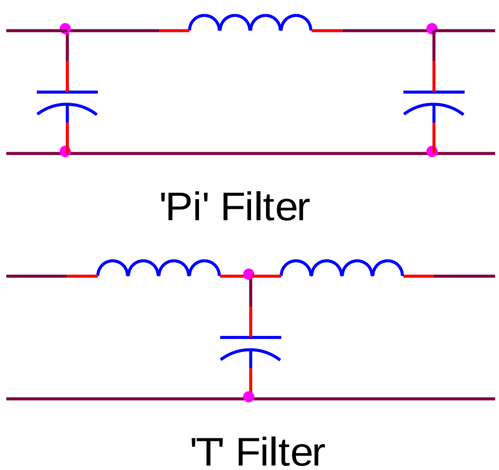

Figure 1 ‘Pi’ and ‘T’ filters

To create these filters within a connector body, connector pins have a ferrite bead passed over them in the centre of the body. On either side of the ferrite bead is an array of capacitors which can be either a PCB with surface mount capacitors or a planar multilayer array.

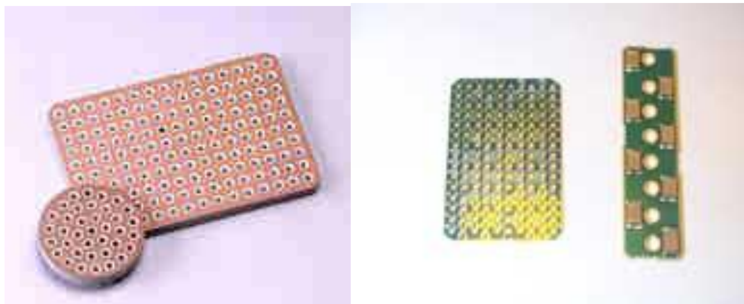

Figure 2 – Planar capacitor arrays.

An example of the physical construction of a filtered connector is shown below.

Figure 3 - Full PI-filter using varistor planar and capacitor planar arrays.

In addition to these L-C filter components there are often additional varistor or diode components which provide transient over-voltage limiting. More recent connectors use varistor planar arrays as well as capacitor arrays [2].

Test Goals when Testing Filtered Connectors

Testing a filtered connector requires confirming the parametric values of up to hundreds of individual capacitors and / or diodes fitted within the body of a connector and wired in very custom ways to suit the end-user application.

In particular the following goals must be met:

- Accurate measurement of capacitance and dissipation factor unaffected by the test adaptor.
- Measurement of capacitance in the presence of bias voltage.
- Confirmation of working voltage capability pin-shell and between pins.

This paper will look at some of the technical innovations used to meet these goals.

Test System Physical and Electrical Architecture.

Applied Relay Testing has created the Reflex 950 - a tester with an electrical architecture designed for filter connector testing that implements the following:

- Dual polarity DC power supplies 0-2100V
- AC Power Supply 0-1500 Vrms, frequencies from 50Hz to 400Hz
- Wide-range DC and AC current measurement of levels and pulses (e.g. for IR and HIPOT).
- A GPIB bus typically used for an LCR meter
- A capacitance bias unit for testing capacitance at working voltage.

- A programmable matrix with 160 Kelvin (4-wire) connections.

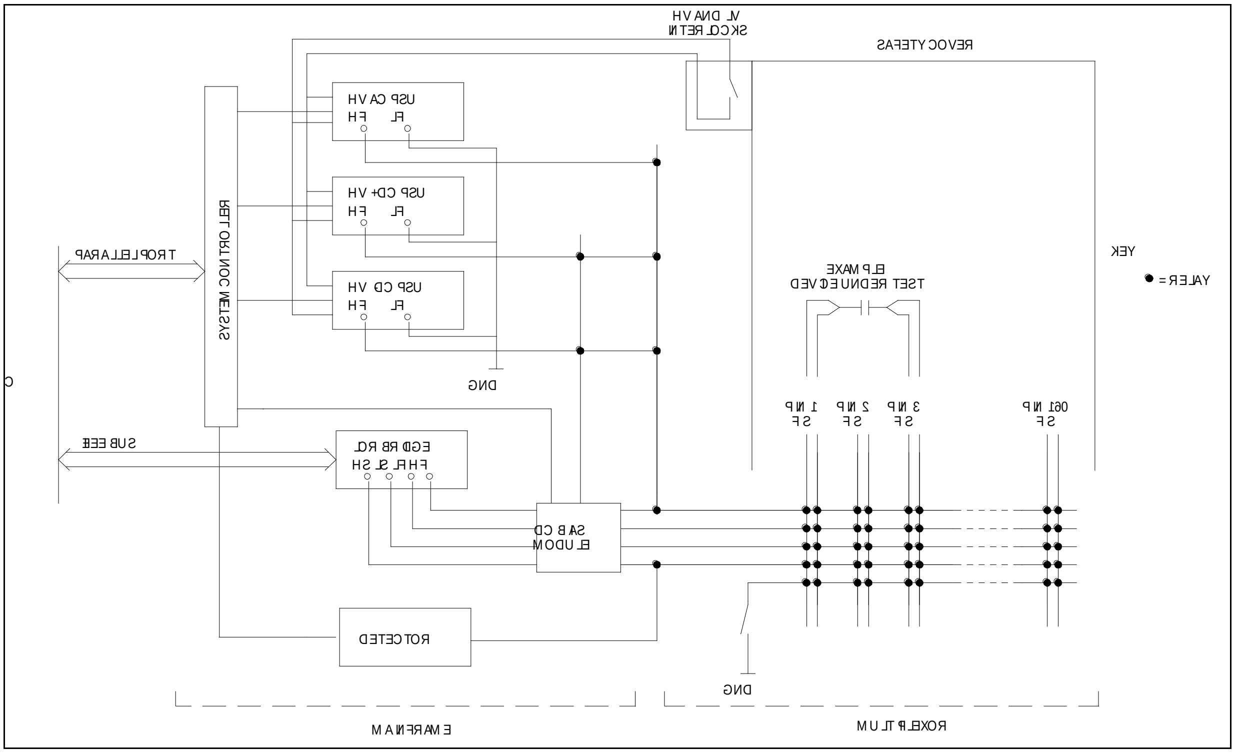

Figure 4 – Reflex 950 electrical architecture.

Table 1 shows an abbreviated list of the major test parameters for this architecture.

Parameter	**Value**
Test voltage	+/- 2100V
Capacitance	1pF – 6uF (measured at working voltage) using chosen LCR meter e.g. Agilent 4263 etc.
DF	0-0.1
Resistance	0.1mR – 1MR
Kelvin connections	160

Table 1 – Specification of this electrical architecture.

Figure 5 - The Reflex 950 Passive Component Tester.

The figure above shows a typical test system layout consisting of a bench height test station with safety enclosure and a pedestal containing the electronics.

Fixturing – The Key to Performance and Flexibility.

Cable assemblies wired to the DUT inevitably introduce noise pickup, additional leakage currents or capacitative strays which can offset otherwise accurate measurements. The best test method for working with filtered connectors should use a fixture implementation that places the DUT as close as possible to the routing switches as shown in Figure 6.

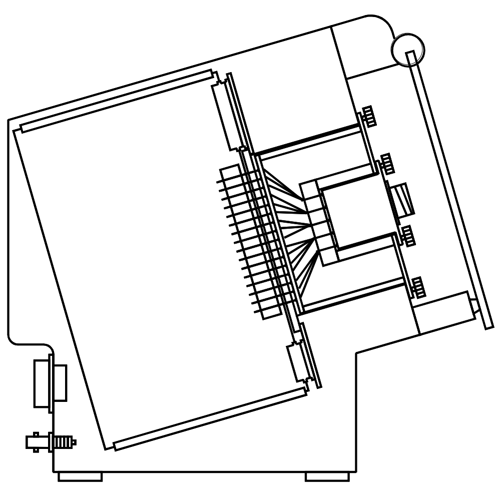

Figure 6 - Fixturing principles, topographical example.

The principle relies on a 'bed-of-nails' – a matrix of spring-loaded test probes which mate with a removable interchangeable test adaptor – a technique proven on the best semiconductor testers for many years. The spring probes are mounted directly on to the switching cards which route to the instrumentation, thus all cable assemblies have been avoided.

The fixture boxes and their electrical connection to the tester are shown in Figures 7 through 10. The metal fixture top plate has a huge useable DUT placement area of around 42 cm by 26 cm whilst the base is made from 4mm

FR4 containing gold mating 'lands' which connect with the spring probes (Figure 8). This solution not only provides an excellent mapping solution for the custom wiring of various devices through to the tester, but its construction ensures a very low leakage environment coupled with an inherently high breakdown voltage, avoiding the need to employ expensive H.V. connectors. Figure 10 shows the detail of the matrix card pins showing the clean electrical environment that follows from using this technique.

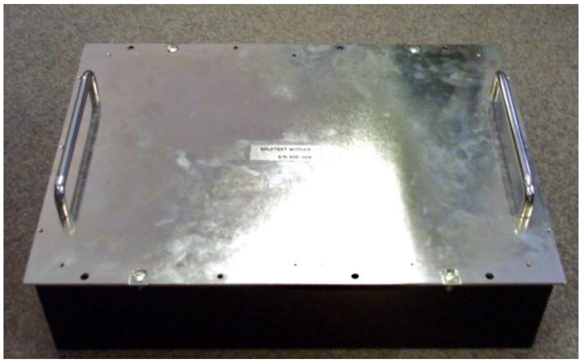

Figure 7 - Fixture adapter for device under test, top view.

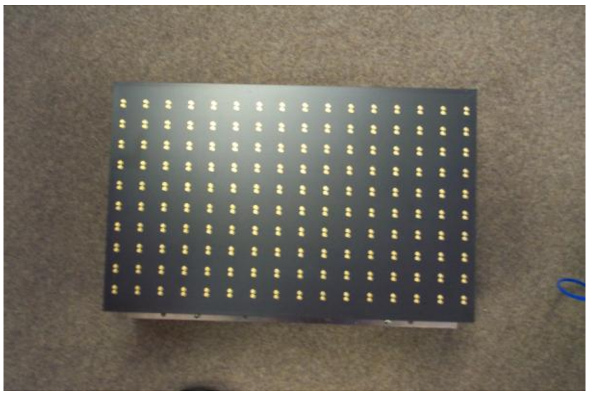

Figure 8 - Fixture adapter bottom view shows Kelvin connections

Figure 9 - The 'bed of nails' that connect to the fixture adaptors.

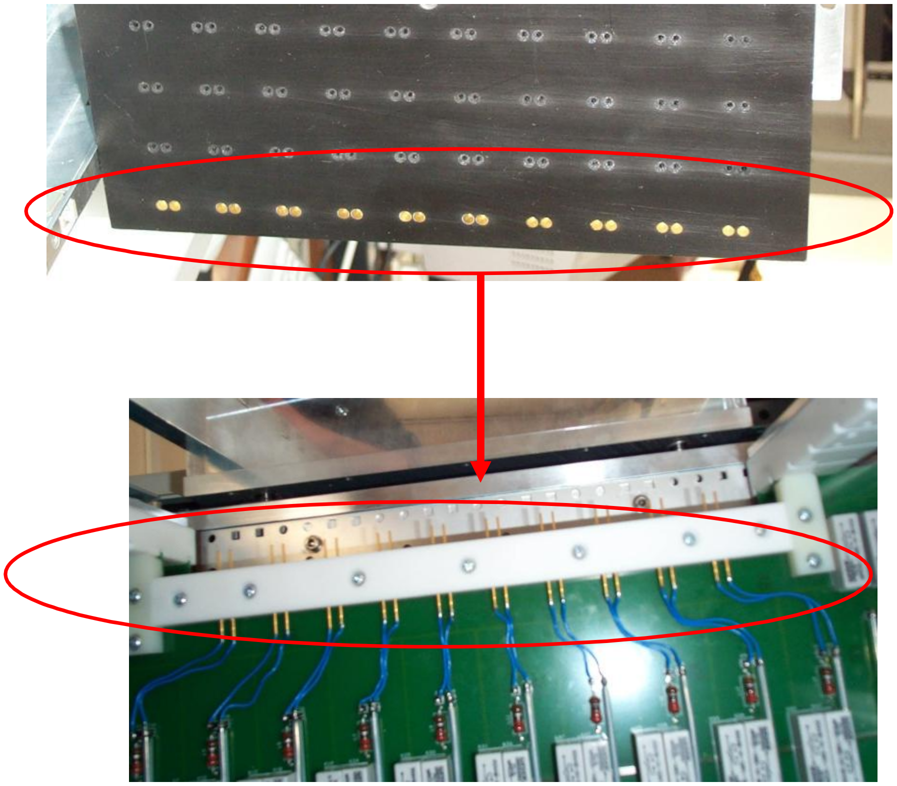

Figure 10 – The matrix card pins mating with the base of the adaptor module.

The typical electrical performance of this mechanical solution is in the region of 10^{13} ohms for a path from device through to the tester – several orders of magnitude greater than the typical 10^{9}-10^{10} ohm specification usually specified for the device under test.

Programming for Filter Connector Test.

There are two mains areas of programming when creating a filter connector test programming:

- Creating the electrical test definition (e.g. applied voltage, capacitance test limits etc)
- Defining the connection route(s) from instrumentation to the device.

Solutions have been created that ease both of these tasks as follows.

Creating the Electrical Test Definitions.

Writing a test program to test filtered connectors should be as simple as possible without requiring formal programming knowledge. A typical test display appears to the Operator as shown in Figure 11. In normal use the Operator can see all relevant information on this single screen without having to navigate away from it. A list of the test steps that comprise the actual test sequence to be performed is displayed as is a 'physical' layout of the device under test that shows the connected pins and the current test route, a great insight into the location of any failure that may arise.

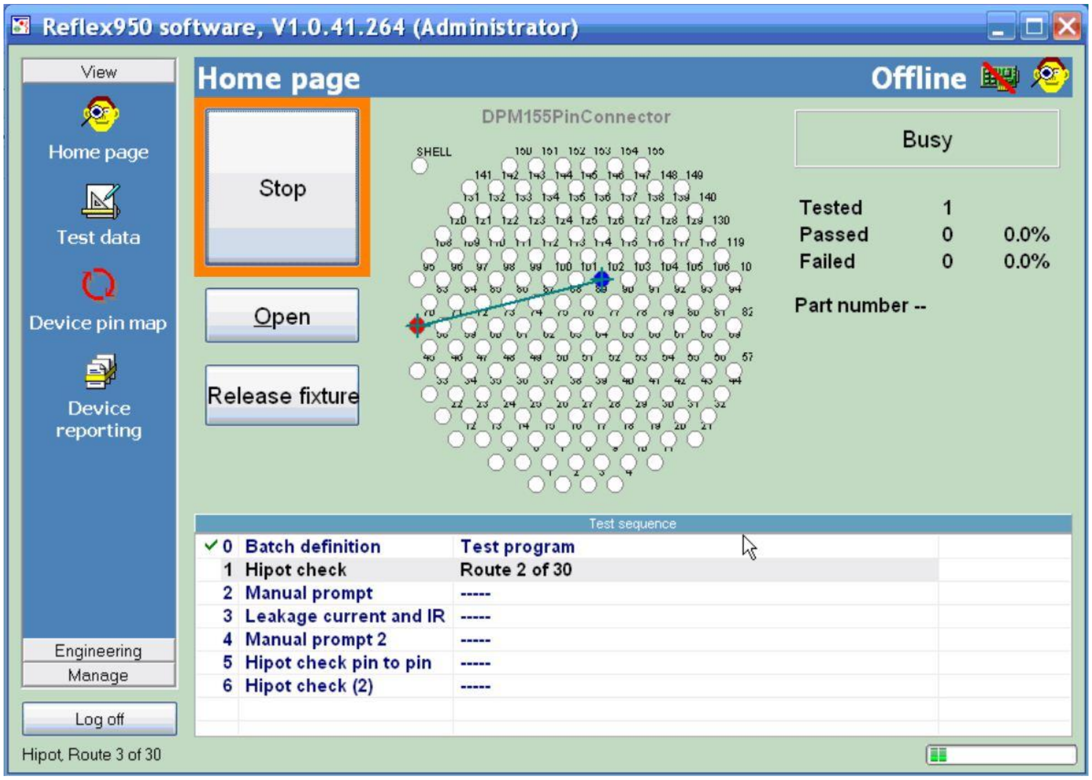

Figure 11 - A typical Operator Screen.

To construct a test program, the Test Engineer chooses from a list of pre-written test types such as HIPOT, IR, Capacitance & DF, Resistance. Each of these test steps is assembled into the required test sequence in whichever order the designer requires. Each test step is able to cover a wide range of electrical parameters and can thus be applied to a wide range of devices.

Programming the Connections between Instrumentation and Device.

The fixture allows customised wiring to map the DUT pins on to it's tester connections but huge flexibility is offered by having each tester connection to the instrumentation fully programmable in software. Choosing this connection is made as intuitive as possible using a powerful pin connection editor shown below in Figure 12.

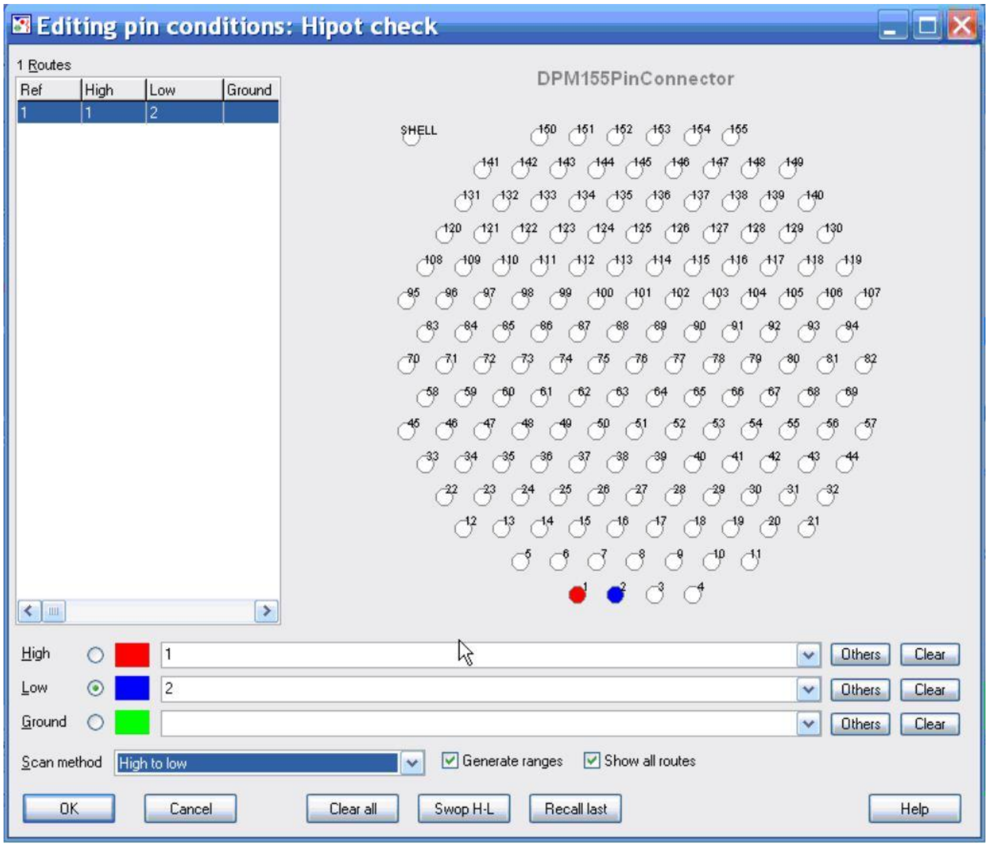

Figure 12 - The Pin Connection Editor.

The editor displays a pre-loaded visual footprint of the DUT shown annotated with DUT-relative pin names or numbers, thus working with this editor is always in terms of DUT nomenclature, further reducing the possibility of programming mistakes. The editor allows the test engineer to specify which device pins will be connected to the instrumentation bus during the test step. The testing of large numbers of similar components such as pin capacitances is also greatly simplified with each test step having the ability to measure a literally unlimited number of test routes for the same measurement parameters. If the pin editing screen in Figure 12 above were used to program the capacitance test, a measurement would be made between pins 1 and 2 only. Add the definition of two more pins to the 'High' pin list as shown in Figure 14 below and now the single measurement is between 10, 15 and 78 connected together and pin 2 as a common. By further changing the specified means of iterating along the entered routes from 'High to Low' to 'High Stepped to Low' the existing test will iterate along individual routes (10 to 2, 15 to 2 and 78 to 2) as shown in Figure 13 below. All of these changes have required no change to the test program electrical parameters.

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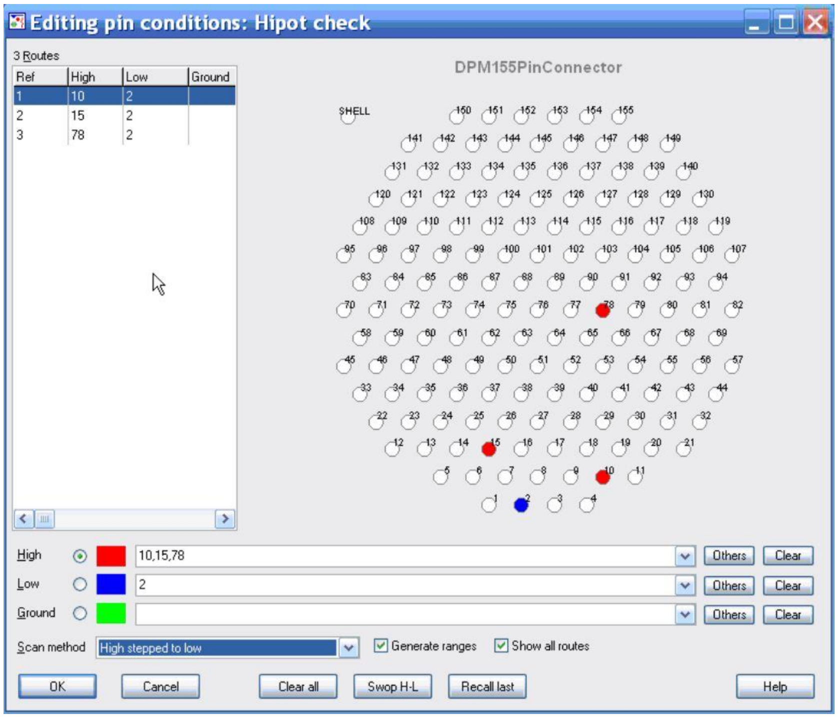

Figure 13 – Specifying multiple pins tested sequentially.

All test routes are individually compared with the specified test limits and marked as a pass or fail as well as being saved to a database file for later report generation. In addition, certain tests such as capacitance and DF allow a 'matching' limit to be specified ensuring that not only do all routes pass for their allowed min and max limits but that all routes are within a allowed difference relative to one another – a further check of quality and consistency. Using this method, any of the Reflex 950 test steps can be applied to any pin or combination of pins that can be imagined. In addition, a ground connection is available permitting one or more pins of the DUT to be held at ground potential during a test if required, for example as a guard against stray leakage currents.

Programming Pin-to-Pin Testing to Ensure no Solder Whiskers.

The Reflex 950 has a powerful algorithm for testing multiple routes in only a few steps. A 'binary-split' iterative technique is used such that by completion of the algorithm, all specified pins have experienced alternate polarities of a high-low connection for example with a high-voltage test to ensure no solder whiskers exist between pins

Measuring Capacitance at Working Voltage.

It is not often appreciated that some capacitor technologies have a marked capacitance versus voltage characteristic. Ceramic capacitors with high capacitance per unit volume can drop in capacitance by several tens of percent when working voltage is applied [3] [4]. For filtered connectors, capacitance measurement is a key parameter because it is directly related to the filtering ability of the connector. It should be measured precisely, both to ensure the filter quality and to compare actual performance with expected performance, further ensuring that there are no manufacturing defects. Under actual operating conditions a filtered connector device pin will (probably) have an operating voltage upon it - perhaps a supply rail delivering power from a power supply - and will be simultaneously performing a filtering task by means of its exhibited capacitance. As a result, the ideal test for filtered connector manufacturers is to be able to measure the capacitance of the connector pin actually <u>at</u> a nominated DC or AC voltage to confirm operation.

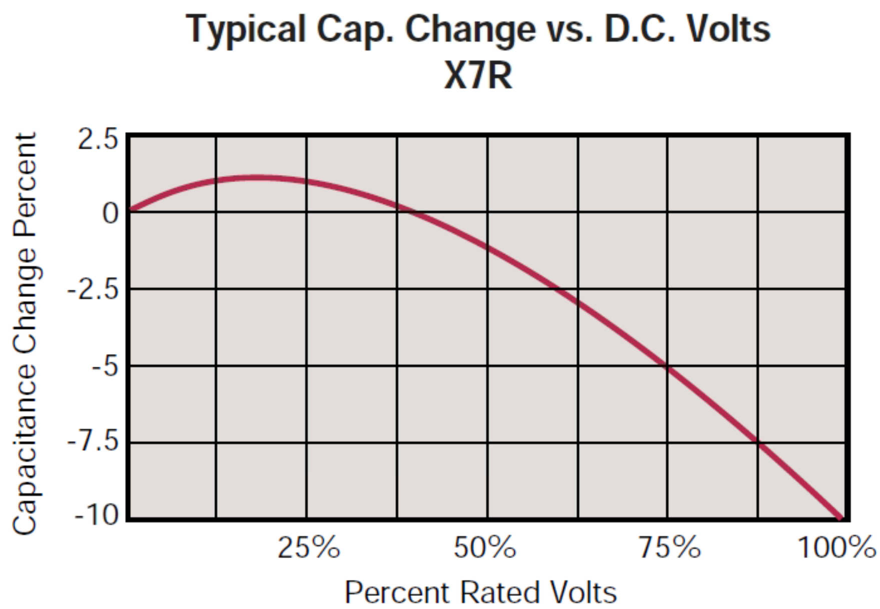

Figure 14 - Capacitance versus applied voltage [2].

To measure capacitance at this working voltage is rather difficult using only a commercial LCR meter since such meters are limited to a few tens of volts of built-in 'bias voltage'. To circumvent this limitation the Reflex 950 includes a novel bias unit which conditions the device connections of a commercial LCR meter such that the device measurement is combined with up to +/-2kV of AC or DC bias voltage, permitting full capacitance and dissipation factor measurements to be made at any desired bias or polarising voltage. Figure 15 shows the block diagram of this technique.

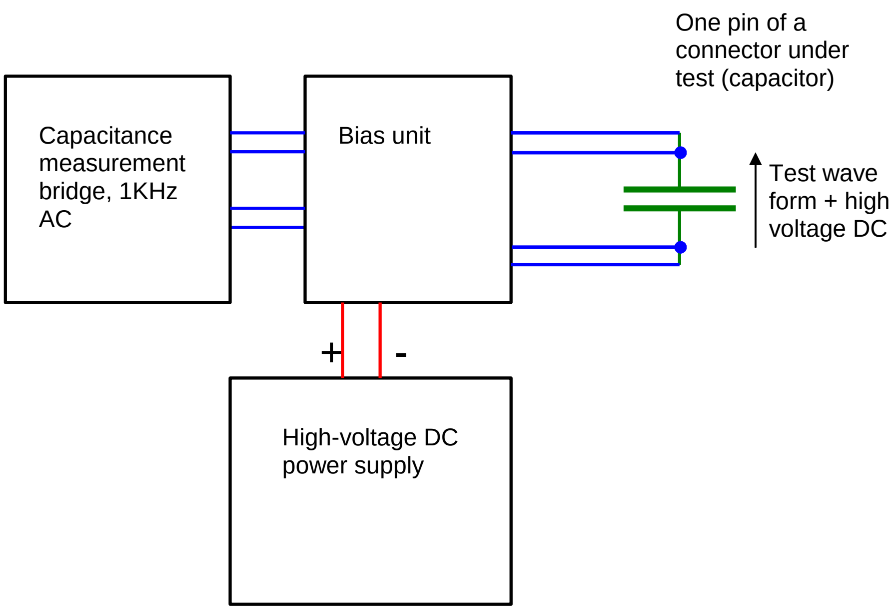

Figure 15 – Electrical architecture of capacitance bias unit.

With this bias module option the filtering ability of a connector can be 100% tested in production instead of relying on sample testing for this characteristic. This has proved to be such a useful test feature that Applied Relay Testing has released the bias unit as a stand-alone instrument.

Conclusion

This paper has introduced test techniques developed for testing filtered connectors. Using the techniques shown, measurement errors have been reduced and the passive components are more fully tested at working voltage. Flexible routing of an electrical architecture to the high number of device pins has been shown to result in a short test programming cycle.

Acknowledgement.

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References.

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[4] Data sheet information on ceramic capacitor dielectrics http://www.avx.com/docs/masterpubs/mccc.pdf.