Capacitor Sounds II - Standalone Distortion Meter.

This article was written for the September 2003 issue of Electronics World.

All measurements to date for this series were made using the test equipment, comprising my real time second and third harmonic analyser as described in the July issue, together with my 1 ppm low distortion 1kHz generator, buffer amplifier and notch filter preamplifier **REF.1** interconnected but otherwise laying ‘loose’ on the workbench. **REF.2** While this arrangement worked exceptionally well, with so many separate exposed modules interconnected by easily broken coaxial cables, it was not particularly convenient to move and store away.

I have since assembled this complete system into a relatively small, 250 × 180 × 100 mm, low cost commercial case, type LC960 purchased from DIL/C-I Electronics, **REF.3** producing a self contained free-standing distortion analyser which can be used testing both amplifiers or capacitors.

As a bonus this arrangement also outputs the notch filter reduced fundamental together with pre-amplified ‘harmonic’ signals for use with a soundcard and FFT software exactly as in my first Capacitor Sounds series. **REF.1** Equally these harmonic signals can be used with my Hewlett Packard 331A distortion meter or my Pico ADC100 16 bit ADC converter improving their distortion measurement capability by 40dB, allowing them to measure distortions 100 times smaller than their unaided minimum. **Fig. 1**

Figure 1) The Real Time hardware system as described in the July issue, fitted into the low cost LC960 250 × 180 × 100 mm case, is shown measuring a 1µF 50v X7R ceramic capacitor at 0.5v using my reference Hewlett Packard test jig. The LED’s respond quickly, revealing how this capacitor’s distortion changes with time and bias voltage.

Modifications to Modules.
To facilitate testing amplifiers, the DC buffer PCB required a minor alteration to isolate the 1µF capacitor C91 from the five 2.2µF capacitors C92-96. As designed to measure capacitor distortions these capacitors were all connected by printed board tracks close to the terminal strip test jig. The five 2.2µF capacitors C92-96 provide DC blocking for the test current which is now taken directly to the “I-out” or far right front panel and test jig BNC connectors. The 1µF capacitor C91 acts to DC block but couple the test signal back into the notch filter for measurement. This capacitor is now taken directly to the “V-in” or second from right BNC test connector.

The BNC outer braids are only used to screen the test signals so the remaining two BNC connector inners provide the earth returns for the measured voltage and test current respectively. These four BNC connectors are arranged at 22mm centres to allow use either with standard Hewlett Packard (Agilent) LCR meter test jigs, my new low cost “terminal strip” test jig or four discrete BNC test leads. **Fig. 2**

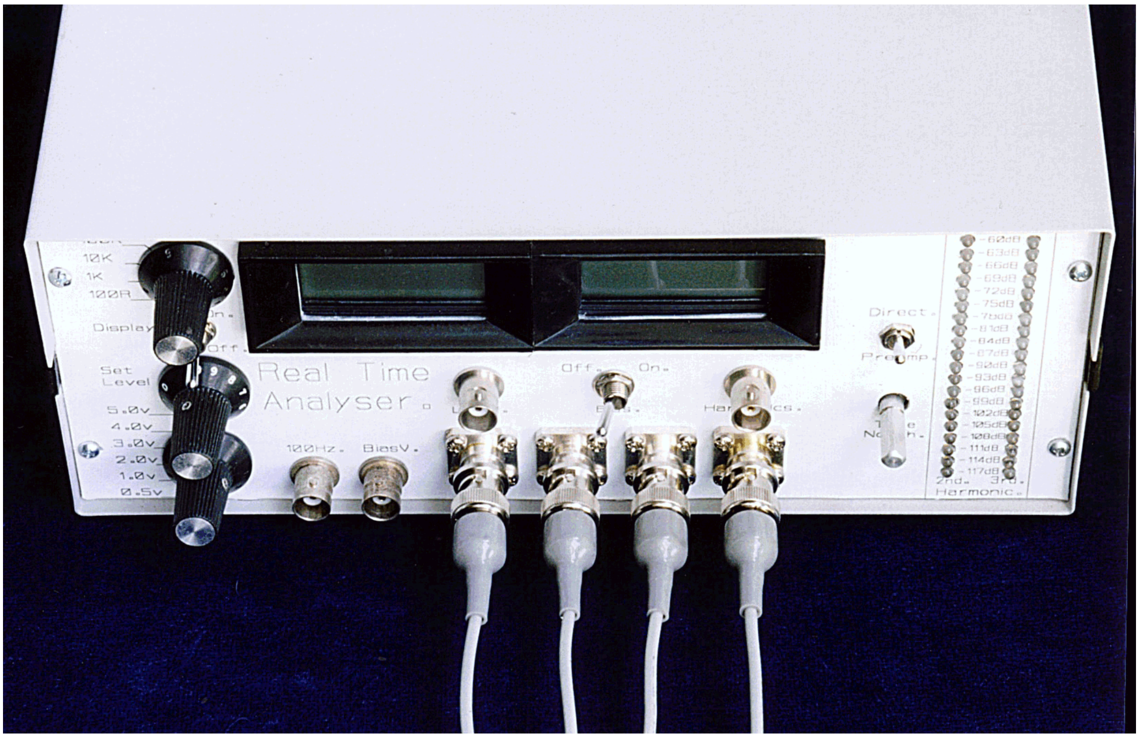

Figure 2)
The four BNC connectors mounted at 22mm centres, provide true four terminal measurements, isolating the test current from the voltage being measured.

Enabling a quick change from measuring capacitors to amplifier circuits simply by change of test jig, with no change of any internal circuitry.

To fit into this case the notch filter module had to be mounted vertically. As originally assembled, the two PTFE insulated terminals on its bottom case side would now foul the case floor so must be removed. Originally these were used as an optional direct input to the notch filter also to input the generator signal into the output buffer amplifier. Both were removed and the buffer's input cable was re-routed to now pass through a hole at the end of the screening case, adjacent to U45.

To fit conveniently into a front panel the display LED's were reassembled 'end on' to their PCB using revised display printed boards. Both LED trees were arranged side by side as two parallel columns some 15mm apart with the forty 3mm LED's now mounted at 4.1275mm (0.1625") centres, so as to fit vertically into this 100mm tall front panel.

Resulting from these changes we now have a more convenient way to measure both amplifiers or capacitors using a permanent set-up which is easily re-configured externally, simply by choice of the external test jigging used or four separate test cables. We have gained flexibility and convenience and improved the noise floor, without degrading measuring accuracy. **Fig. 3**

Figure 3)
Testing the 1µF 250v B32653 capacitor which featured in my last article, mounted in my easily fabricated, low cost, four terminal 'replica' capacitor test jig made from a 100mm length of 15mm Aluminium angle, four panel mounting BNC connectors at 22mm centres and a terminal test strip.

While not part of my original intention, I now see this arrangement of case mounted modules, would also benefit those readers who have built only the original generator, notch filter and DC bias printed boards and have no wish to build the Real Time add-ons.

Simply omit the Real Time hardware printed board complete with its LED displays and front panel level switch. The two panel meters could then be arranged to continuously display both the DC bias voltage and the AC test voltage being used.

Appearance.
While the basic metal working needed is quite straightforward using only hand tools, the most difficult aspect of any self assembled test equipment is producing a suitably legended front panel. Over the years I have tried many methods, with some success. In past years few viable options existed, one could use 'Letraset' or similar transfers, cut a silk screen stencil or make an engraving onto the black/white two colour Traffolite or similar plastic laminate.

More recently the best method I found, which was used for the front panel label of my Tanδ meter, was the excellent but relatively expensive 'Quick Mark' peel apart photosensitive label system from Mega Electronics **REF.4**. This could be used to provide both positive and negative images from a positive master. Even the 0.5pt lines in my logo were clearly legible.

Mega now offer a lower cost, directly laser printable, A4 sized self adhesive label system called 'Quick-Laser', which can be easily overlaminated for extra protection. Quick Laser is a plastic film available in silver, yellow, blue, green or the white which I used for this assembly. **Fig. 4**

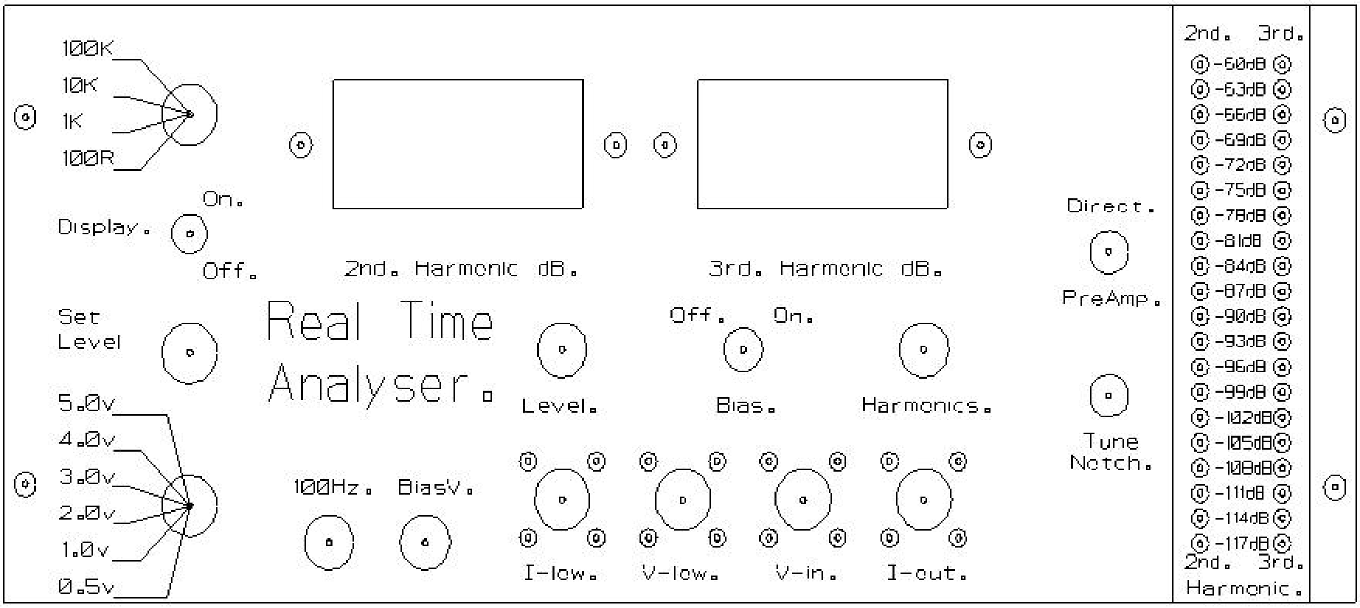

Figure 4) True scale front panel layout as used for my prototype assembly. This drawing is available on my CD ROM as true size PDF file which can be directly printed, also as a fully dimensioned drawing.

DC bias PCB.
Having cut and drilled the case front panel, the first assembly stage is to modify this PCB. Remove the source impedance resistors R91-94 and R97-99, replacing R94 only with a link wire.

Remove the charge discharge toggle switch and relocate onto the front panel, then cut through and remove the three PCB tracks which connected C91 to the five 2.2µF capacitors C92-96 also the charge/discharge resistor R95. Insert an insulated wire link from the now free end of R95 to re-connect to all five 2.2µF capacitors C92-96.

To assist in earthing the coax cable from the I-out front panel BNC also the I-low return current wire, I added an extra vero pin to earth, close to the bias output terminal connector strip where shown on the figure. **Fig. 5.**

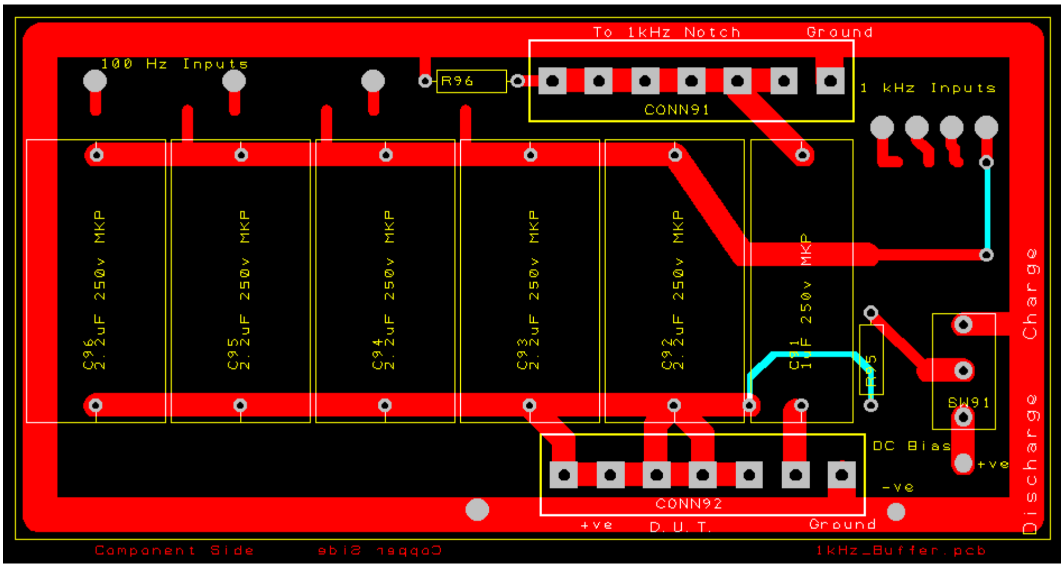

Figure 5) Screen shot showing how I modified my original DC bias printed board for use in this cased assembly.

By simply cutting three tracks and adding a short link wire, I isolated C91 from the five 2.2µF C92-96 capacitors to provide full four terminal capability to the test jig, allowing capacitor or amplifier distortion measurement.

Low Distortion Oscillator Module.
To facilitate periodic re-calibration of this oscillator, without removing from the case, I drilled three 6mm holes which are aligned over the three multi-turn pre-set resistors. To prevent stray cut wire ends falling inside this case during construction, these holes were covered by three removable blue sticky labels, as seen in the photo. Because this assembly sits over one case side flange, also the Real Time range switch spindle extension, a piece of scrap copper laminate was affixed, copper side down, underneath this module using four 2mm screws and spacers at the mounting pads provided on the PCB.

In addition to protecting the printed tracks from damage, this earthed copper laminate provides additional screening, further reducing generator noise and distortion. You should also refit three longer power supply leadwires and re-connect the coax cable between this module output and the notch filter input, before finally mounting the module into the case.

I used PTFE insulated coaxial cable simply because while it is harder to strip cleanly, I find it facilitates soldering into position without risk of damage to the inner core insulation.

Notch Filter/Preamplifier and Output Buffer.
As for the oscillator module, the track side of this module also was screened and protected using scrap copper laminate affixed using four 2mm screws. Note the top most screw adjacent to the panel meter clashes, so should be left out.

Two PTFE lead through terminals on the case wall opposite to the range switch, conflict with the LC960 case bottom when this module is mounted vertically as shown, so must first be removed. Remove also the short coaxial cable which connects between the test jig terminal strip and notch filter preamplifier input and the coax cable which originally connected between the oscillator output and the output buffer amplifier input.

Fit one end only of each of three new coax cables, to the buffer 50Ω output tag, the notch filter preamplifier input tag and the buffer amplifier input tag through the hole in the case end adjacent to U45. The free end of the notch filter input coax will be connected to the DC bias buffer PCB output terminal strip and the buffer amplifier input coax re-connected to the oscillator output terminal.

The free end of the 50Ω output tag cable will later connect to the wire link replacing R94 on the DC bias PCB, via the new front panel mounted source impedance selector switch.

Three more coax cables also power leads will be connected to this module but are best fitted later, after it has been finally mounted into position inside the case.

Trial/initial Assembly.
Temporarily fix all switches, BNC connectors, panel meters in place on the un-legended front panel and assemble to the case. The PM128 panel meter bezel adjoining ends may need reducing by some 0.5mm to fit into this panel layout. Check to make certain all remaining front panel modules fit correctly then dismantle and fix and trim the front panel label in position. Refit all front panel switches and BNC connectors, but do not refit the panel into the case or install the modules.

Fit and solder all required coax and wire leads to the front panel hardware also the two panel meter displays, but leave the new source impedance selector switch to later. Fit in place the DC bias PCB and connect to the front panel wiring as needed, then refit the front panel to the case.

Install the generator module and notch filter/preamp modules and connect up the free end of the notch filter input coax to the DC bias buffer PCB output terminal strip, to the left side terminal strip as seen in the figure 6. **Fig. 6.**

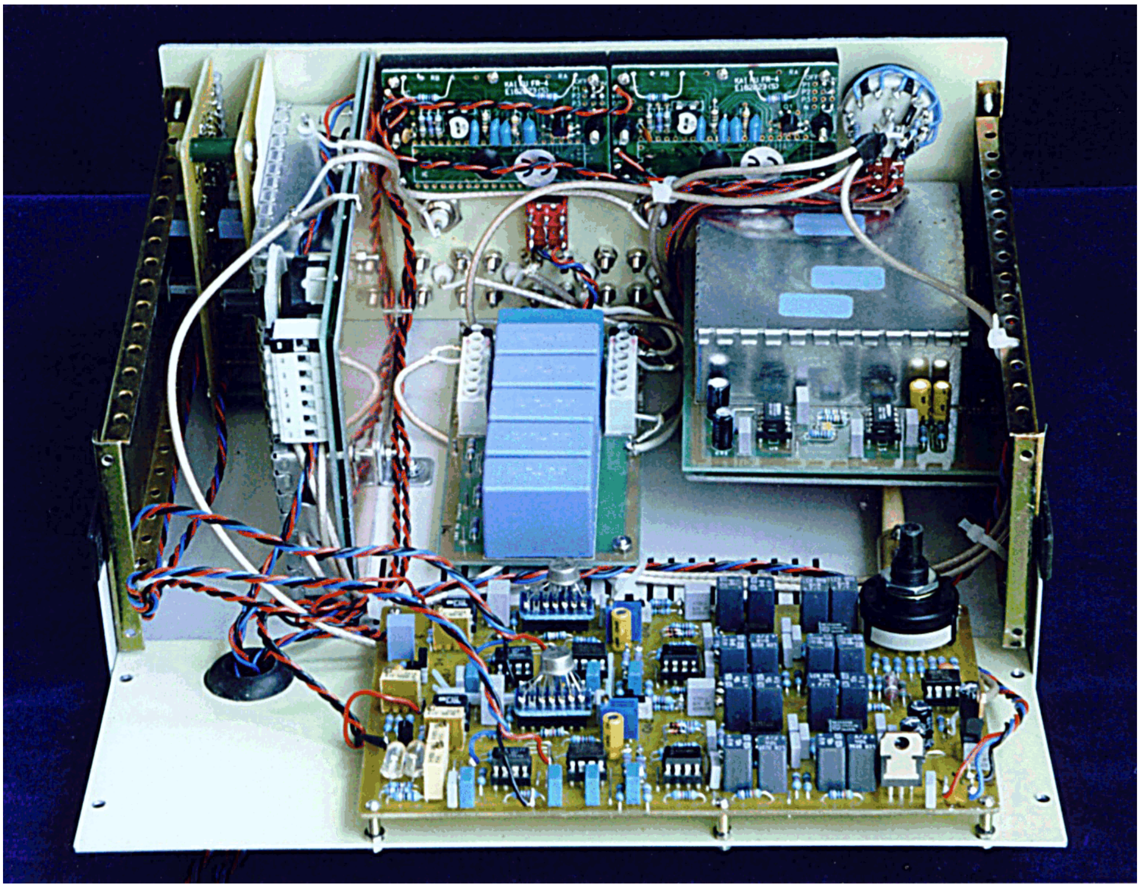

Figure 6)
Rear view with the back panel laid flat shows the various coaxial cable connecting between the modules and front panel, in my assembly.

The right hand top switch, with three coax cables is the new combined 100Hz and 1kHz source impedance selector, with the 100Hz source impedance arranged ten times larger than for 1kHz, matching the capacitors impedance at these frequencies.

Source impedance switch.
For this I used a three pole four way switch with two poles connected in parallel and used for the 1kHz source resistors which were mounted directly onto the switch tags. The remaining pole was used for the 100 Hz source resistors. Both 100 Hz from the front panel and 1kHZ from the buffer amplifier 50Ω output coax tag go direct to their relevant resistor chains, so as to supply both frequencies at the required source impedance, direct onto the wire link which replaces R94 on the DC bias PCB.

Final Wiring.
Connect the two short coax lengths from the front panel ‘Level’ and ‘Harmonics’ BNC connectors to the meter and harmonics out PTFE terminals on the notch filter/preamp assembly and connect the power supply cables to the PCB tags.

Assuming the Real Time display modules are not being used, all wiring is now complete and the assembly can be tested.

Real Time Modules.
Drill and fix the main PCB to the case back panel such that the input end of this PCB is fixed some 20mm from the left side of the case back, using seven 2mm screws and spacers fastened through the mounting pads on the PCB. Screw the two LED display boards together using 13mm plastic spacers and insert the LED’s into the front panel drillings. It is essential the track side of the display board nearest the notch filter/preamp module is insulated. For this I used a piece of 1mm thick ‘plasticard’ from a model shop, but any similar thickness and insulator type will suffice, see Figure 6.

Connect a coax cable between this PCB input terminals and the notch filter/preamp ‘harmonics’ PTFE output terminal. This is the coax cable seen far left in figure 6. For convenience I powered the panel meters using PP3 batteries, simply tucked away under the generator module and retained using ‘sticky fixer’ pads.

Connect the LED display PCB’s to the 15 volt out terminals, the OutA, OutB 2kHz and 3kHz vero pins as appropriate. Connect both panel meter inputs to the Out2nd, Out3rd dB vero pins with both negative inputs connected to the 6v reference output and attach power supply leads. **Fig. 7**

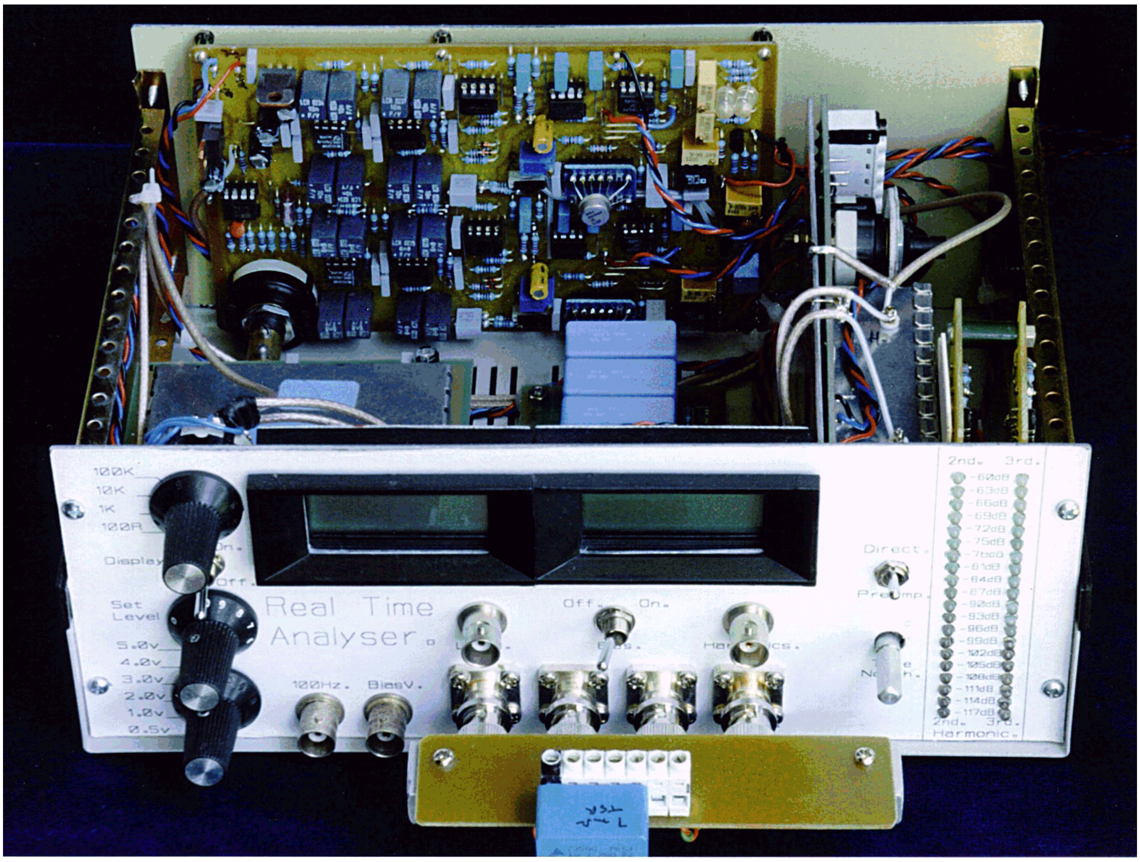

Figure 7) The same assembly now viewed from the front shows the Real Time printed board mounted on the case back panel.

This view also shows the added insulation inserted between the LED display board and the notch filter/ preamp case lid.

This completes the assembly which can now be tested. Using a 3 volt test level and measuring either a good 511Ω metal film resistor or a good 1µF metallised Polypropylene capacitor, both panel meter displays should read better than -120dB and all display LED's should be off. **Fig.3**

Test Jigs.
Throughout my CapacitorSounds series I have repeatedly stressed the need to use good test jigs. I fortunately have several of the excellent four terminal Hewlett Packard LCR meter test jigs, having standardised on these for all my tests and measurements, whenever practical, many years ago.

However while these jigs are properly designed and of excellent quality they are expensive, so I don't expect many readers will be similarly equipped. I have designed a low cost alternative jig assembly which can be seen in use in figures 3 and 7 testing the excellent 1µF 250v B32653 metallised Polypropylene capacitor which featured in my last article.

This jig was assembled using a 100mm length of 15mm Aluminium angle, four panel mounting BNC connectors, Farnell part 3650534, mounted at 22mm centres to match my front panel and a terminal block as used for my DC bias buffer. **Fig. 8**

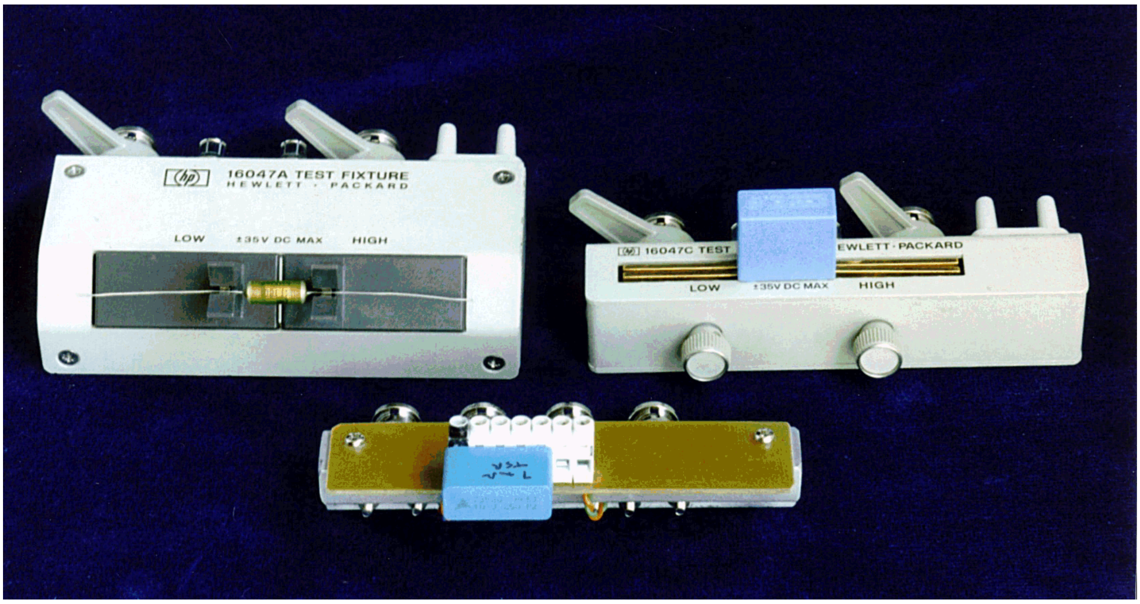

Figure 8) The jigs used for capacitor measurements. The HP16047A jig left, has plug in exchangeable adapters for axial and radial leaded components. The HP16047C jig right, my reference standard, has gold plated contacts which clamp onto component leads. My low cost alternative, is shown for comparison.

The terminal block was mounted on a scrap piece of laminate and its active or White terminals simply isolated by hand carving. The Black common (low) terminal was connected to both the current and voltage 'low' BNC connectors using a short length of twisted pair wires, with the wires placed one on each side of the terminal pin solder.

In similar fashion the White (high) test terminal pins were connected to the 'high' BNC connectors with the voltage wire to the test terminal adjacent to the common terminal, the current wire going to the opposite end terminal pin. In this fashion full four terminal connections were maintained right up to these capacitor test jig terminals.

Performance.
Using a 3v test level and with the original calibration module unchanged, my 1µF 250v Foil and Polypropylene FKP reference capacitor now reads better than -130dB both for 2nd and 3rd harmonics, a clear indication that the improved screening with the modules assembled inside the case has lowered noise levels and reduced extraneous noise pickup. Altogether a significant improvement on an already excellent measuring system.

In my next article I explore using this equipment to measure distortions in amplifier circuits.

End.

References.

1) Capacitor Sounds. C.Bateman. Electronics World, July, September, October 02.

2) Capacitor SoundsII. C.Bateman. Electronics World, July 2003.

3) DIL/C-I Electronics, Holland. email to dil@euronet.nl

4) Mega Electronics Ltd. http://www.megauk.com

Technical Support.
Full details of this new hardware test method and my original Capacitor Sounds series 1 ppm low distortion oscillator, buffer amplifier, notch filter/preamplifier and DC bias assemblies, together with parts lists, assembly manuals and full size printed circuit board drawings, all as .PDF files arranged for easy viewing on screen or hardcopy, are provided in my new "Capacitor Sounds" CD.

This CD ROM includes updated and much expanded re-writes with very many more figures, of my recent series of six 'Capacitor Sounds' articles, supported now by some ninety capacitor distortion measurement plots. Also on the CD are PDF re-writes of my earlier 'Understand Capacitors' series together with articles how to diagnose failed capacitors while still mounted on printed circuit boards and essential low cost capacitor measurement methods, more than twenty popular articles.

The CD is now available, cost £15 Sterling including post packing. Send cheques or postal/money orders in Pounds Sterling only to:-

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