A PASSIVE ROLE?

Capacitors & Resistors come under Martin Colloms’s scrutiny.

Those readers who have been following my writings over the last eight years or so will be aware that I have changed my position regarding audio technology over that period from that of a rigid advocate of active engineering to a more flexible view of technology and its interaction with reproduced sound quality. Too many ears, including my own and those of a number of respected colleagues, are reporting sound quality differences which, at present, are not adequately anticipated by established audio engineering principles.

In the May issue of HFN/IR, I summarised my empirical findings on amplifiers, these based on my experience of a wide variety of different designs and technologies, with the conclusion that “technology” in the accepted sense did not adequately describe sound quality. Indeed, it is now possible to construct two amplifiers of very similar performance, both meeting an exhaustive specification far in excess of that traditionally required for flawless reproduction, yet find significant subjective quality differences between them.

Experiments with cables have shown that a piece of wire is not the simple distortionless link we have assumed it to be. Likewise, the non-amplifying, non-“electronic” electrical components—resistors, capacitors and inductors—the so-called “passive” components, can also have an influence on sound quality not immediately connected with their use as circuit elements. If these passive parts are not so passive after all, then where does the effect of the cables, the resistors and the capacitors leave off and where does that of the amplifier proper begin?

In fact, the effects are inseparable; logically, a good amplifier must use a combination of good technology, intelligent circuit design, optimum passive components and the right wire. The problem is thus rather one of where to start.

With this background preamble over, our present exercise is to find out for ourselves, in a very straightforward way. The first thing was to set up an audio system of as high a standard as was practicable, with the choice of optimum cable going without question; secondly, we used that system as a reference chain within which to observe differences, hopefully even improvements (these defined as changes in the recognised ‘right’ direction); thirdly, whenever possible we incorporated the change responsible for an improvement within the reference system, and thus moved the overall sound quality still further forward. By this means, a system could be refined to a point where even small component changes might exhibit a clear effect on the system. The programme used was chosen to demonstrate soundstage width, depth, ambience, and focus, tonal and musical neutrality, good transient reproduction and as high a level as lifelike dynamics. It included music played on the excellent range of Magneplanar MGII loudspeakers, Audio Research SP-8 preamp and D-115 power amplifier, Linn Sondek, Rega RB300 tonearm, van den Hul MC1000 m-cartridge, Sony ‘552/702 CD player, with interconnects consisting of LC single-strand cable. Such a system, however, is not mandatory to detect distinctive differences and does not need to be overly expensive. Cable differences can be audible and significant in a £500 vinyl disc system or a £750 CD-based system.

For the purposes of this article, the majority of the results are anecdotal, reporting what happened—or, as some may prefer to see it, what we thought happened—when a passive component was inserted or substituted. These assessments were carried out in the same manner as for other hi-fi products, with much the same attitudes present in the listeners’ minds, the main differences being due to the large number of ‘products’ available. While readers must decide themselves whether or not to take the subjective findings on trust, a small number of controlled double-blind tests were also undertaken, and the results from these tests are presented separately.

CAPACITORS: TEST ONE

The capacitor was the primary target in this survey. Visually dominant, available in many different shapes, sizes, configurations and colours, they have been the subject of much written speculation on whether their audio performance conforms to that of the ‘perfect’ capacitor used by circuit designers. For this first series of tests, the capacitor under test was inserted between the pre and power headstage, using a simple AC coupling link. Although this will give a high-pass filter action, the impedances involved—600ohms source, 200k-ohms load—meant that capacitor values down to 0.47µF could be used without significant LF rolloff above 20kHz. The upper size limit is effectively unbound, and we went as high as 10000µF (10milifarads) in order to get some idea of the audio quality of power supply components.

The Electrolyte especially wanted to include some Tantum electrolytics in this test, but they were not available for the listening tests, so the results for these tests will be included in a later issue.

We have determined that sound quality was, of course, the direct connection, which scored 95% on our scale of subjective judgment. By contrast, the insertion of the component under test—I must stress that this was a single series capacitor—resulted in a score ranging between 0% to 50% on the same scale. The insertion of capacitors scoring towards 91% was hard to detect, but at the 50% level, the insertion resulted in a clear modification of the sound of the reference system, even when no other improvement had been substituted.

Here, then, are the results for this test, with the score corresponding to their approximate performance in the listening tests. Note that any particular capacitor may not always be applicable for other values of the same type, unless the constructional details are very similar.

C1 Make: Sidereal
Value: 5µF 200V
Dielectric: Metallised polypropylene
Comments: This US-made capacitor with multistrand copper leads is available from RATA in the UK. Compared with other types it showed noticeably better definition at both treble and bass extremes. The mid was in the top class for tonality, clarity and depth.
Score: 81%

C2 Make: Ultracap
Type: CE323 series
Value: 4µF 210V
Dielectric: Metallised polypropylene
Comments: This white cylindrical US-made device is the latest version of the familiar capacitor made popular by Peter Moncrieff’s IAR magazine and appears in many high-end products. With the Sidereal, it leads the field.
Score: 88%

C3 Make: Ultracap
Type: CE323 605220
Value: 6µF 210V
Dielectric: Metallised polypropylene
Comments: Sound similar to C2
Score: 83%

C4 Make: Ultracap
Type: CE323
Value: 2µF 210V
Dielectric: Metallised polypropylene
Comments: This white cylindrical capacitor had a good HF performance, but some loss of ambience and space were noted in the lower frequency range.
Score: 83%

C5 Make: High Lambda
Type: Taitsu 2A205K
Value: 2.2µF
Dielectric: Polypropylene
Comments: A large, very costly plastic film type, much in favour for very high quality crossovers. It showed some slight mid sharpness and hardening, a touch of treble fizzle and mild loss of bass control.
Score: 83%

C6 Make: Woom Cap (Re-Cap)
Type: PP3MF 106K2.5A
Value: 10µF 250V
Dielectric: Polypropylene
Comments: A large yellow flat film capacitor, US made, used extensively by Audio Research and Counterpoint. Sound had good midrange character, fine depth and ambience, but there was some loss of definition and a slight tizz in the treble.
Score: 75%

C7 Make: WIMA
Type: WT-WT2A 335K
Value: 3.3µF
Dielectric: Not known
Comments: This is a Japanese high quality plastic film capacitor selected for audio quality. It had a pleasant sound, with good stereo focus but some loss of depth, as well as a slight nasal coloration, a slight ‘booming’ and the upper mid-treble was up.
Score: 70%

C8 Make: MKP
Type: MK P10
Score: 70%
C17 Make: RIFA
Score: 65%
Type: Miniprint PHE280HF722
Value: 2.2µF
Dielectric: Poly carbonate
Comments: The sound of this Swedish-made component was a touch 'loud' and forward, with a bright, slightly 'itty' treble. Tight and well-defined, however.

C18 Make: Proscan Filmcap
Score: 65%
Type: 85C
Value: 10000µF 100V
Dielectric: Aluminium electrolytic
Comments: A UK-made standard heavy duty power supply electrolytic; it gave some bass lumpiness, with a loss of midrange and midfrequency. The sound was slightly defocused, with some LF 'fuzz'.

C19 Make: Proscan Filmcap
Score: 63%
Type: 85E
Value: 10000µF 40V
Dielectric: Aluminium Electrolytic Comments: A lower voltage high current reservoir cap designed to Denis Morescroft's specification, this gave the sound with some added hardness and a grainy effect, with the treble a touch bright. It was nevertheless fairly clear and well-focused.

C20 Make: STC
Score: 58%
Type: ALT20A 103DD040
Value: 4700µF 100V
Dielectric: Aluminium electrolytic Comments: A medium-grade reservoir cap with tag connections, this gave the sound some mid-forwardness, with a loss of stereo depth and some bass 'boom'. There was a loss of stereo focus, plus an odd 'filtered', bandwidth-limited effect.

C21 Make: STC
Score: 58%
Type: ALP20A 103DD040
Value: 10000µF 40V
Dielectric: Aluminium electrolytic Comments: A multi-tagged version of C20, this gave a well-balanced sound, but with a hint of upper-range harshness.

C22 Make: RS Components
Score: 56%
Type: RS115-168
Value: 2.2µF
Dielectric: Metalised polypropylene Comments: This orange capacitor gave some mid coloration with a 'hooky' effect, but with fair stereo depth and a reasonable overall balance.

C23 Make: STC
Score: 55%
Type: K104A 103T0405F
Value: 10000µF 40V
Dielectric: Aluminium electrolytic Comments: A modest power supply electrolytic, this gave a bland smooth effect, with a loss of dynamics. There was some loss of focus, with a touch of nasality. Treble was average; bass was somewhat soft.

C24 Make: C1
Score: 54%
Type: 2A 305K U-Con L
Value: 3.3µF 100V
Dielectric: Mylar Comments: This Japanese capacitor is especially selected for audio. However, it gave some mid coloration and treble grain, with a loss of stereo depth.

C25 Make: Rubycon
Score: 51%
Type: 3.3µF 100V
Dielectric: Mylar Comments: This Japanese audio 'special', with Litze wire terminations. The sound was coloured in the midrange, with a general loss of depth and definition, plus some 'grain' in the treble.

**CAPACITORS: TEST TWO**

This test was devised to see whether any correlation could be established between the rankings for the 10000µF power supply electrolytic reservoir capacitors used when they were used as coupling capacitors in Test One and those for their more normal use. A modest test amplifier, a Rotel RA820BX — a promising choice in view of its generally good sound and desirable power transparency — was modified, bringing the power supply connections outside the case to facilitate quick and easy connection to a variety of reservoir capacitors. Aside from the substitution of the Rotel for the IS Audio Research amplifiers, no other change was made to the test system, although as the amplifier used for Test One cost 33 times the price of the Rotel, some doubt was expressed as to whether any audible results would be obtained. (Although the marking is to the same absolute scale as used before, the marks for each capacitor relate to its use in the Rotel, which scored 45% on this scale when unmodified.)

C12 Make: STC
Score: 65%
Comments: More powerful, better defined bass; better treble detail and focus.

C9 Make: Proscan Filmcap
Score: 60%
Comments: This Denis Morescroft-inspired cap gave a well-balanced sound, quite clear, with a sweet treble but slightly softened definition.

C10 Make: ROE
Score: 60%
Comments: Good bass, depth and detail; quite dynamic, with clear treble.

C18 Make: Proscan Filmcap
Score: 55%
Comments: This standard cap was generally similar in its effect to the Morecroft version, but had reduced definition and depth, and less clarity and attack in the treble.

C20 Make: STC
Score: 50%
Comments: A small improvement over the standard capacitors fitted to the '820BX, but with reduced depth compared with the better types, as well as some muddling of detail, loss of bass definition and soundstage.

C10/C1 Make: ROE, bypassed with 5µF Sideral
Score: 62%
Comments: A surprising change in tonal balance occurred, considering that the plastic film capacitor represents just 1/200th of the total capacitance. The tonal balance of the ROE shifted nearer to the pleasant neutrality of the Morecroft Proscan. Definition was still good, while subjectively the bass seemed a little 'slow'. Overall, the score remained almost the same.

**CAPACITORS: TEST THREE**

The results of this test are not presented in any great detail, but are interesting none the less. In this test, the reservoir capacitors were used as low impedance power amplifier-loudspeaker couplings. Power levels were kept low to minimise reverse gain effects, as the test was being operated without any DC bias across them. The peak power level was 2W into 4ohms (Magneplanar MGIII), with a mean level of 200-600mW, typically just 1.4V AC rms.

All the capacitors used showed moderate differences in sound quality and all lowered the standard of replay when compared with the straight wire connection. The rankings...
were very similar to those observed in Test One.

**SUMMARY: TESTS 1, 2, 3**

The three tests auditioned the sample capacitor as appraisals in a high impedance, small signal, coupling mode; in a low impedance, higher current, coupling mode; and as power supply reservoirs, 'outside' the signal loop of the test amplifier. In all three cases, significant differences in sound quality were observed.

Regarding the large power supply electrolytics, it was surprising to discover that each possessed an inherent sonic characteristic or signature which was identified in each of the tests. Nevertheless, this is considered too be low to be significant.

**DOUBLE-BLIND TESTS**

For this report, a series of double-blind tests was arranged. The test panel comprised some statistically solid data to support or deny the assertions concerning the effect on sound quality of the various capacitors auditioned earlier. The components under test—both transistors and amplifiers—were supplied by an independent vendor. The test results have been considered to be too low to be significant.

The results of this double-blind test confirmed the experience of the Audiolab designers, who had decided that the capacitor should be omitted except in cases where essential to block DC.

**ASSOCIATED TEST RESULTS**

A) A similar test to the third test was carried out using an existing transistor amplifier with excellent common mode rejection. A panel of four skilled listeners comparatively auditioned an unpaired set of amplifiers, with one of these undergoing capacitor substitution. Four makes of capacitor were tried, including Mitsubishi and Rubycon types. The ratings cannot be disclosed, but the results showed that each type imparted distinct and recognisable signatures to the amplifier's output. One gave exceptionally treble quality, for example, and a clear midrange, at the expense of a softened bass, while another was well-balanced, without being particularly outstanding in any area. Another gave taut, firm low frequencies but a grainless treble, and the fourth was slightly soft at the frequency extremes, but excelled in terms of stereo depth and ambience through the midrange. The differences were reliably identifiable, though the panelists didn't reach any clear decision about which of the four was preferable.

B) Nearly all CD players use an output coupling capacitor, usually an inexpensive electrolytic. Several recent models, tested over the last three years have shown that the sound quality of such a player can be altered and in many cases improved by substituting a better type. Where the following amplifier or preamplifier all used low cost standard tantalum, two pairs of each type were tried, this time with an overall better results still. Careful comparative listening, involving reference to a constant 'standard' player, has confirmed improvement to some degree of the sound quality of the following players by substitution to a capacitor of higher quality. The Marantz CD-73, Yamaha CD-X1, CD-X2, CD-3 and related models; and the Akai CD-M8.

Similar modifications have improved the sound of Counterpoint SA-7 and Audio Research SP-8 preamplifiers. Corroboration has been extensive, involving (certain of) the manufacturers concerned, many owners of CD players, and other writers.

C) In the January 1985 issue of **HFN/RR** (p35), I reported the results of a double-blind test involving two nominally identical Audiolab power amplifiers, where a small subjective difference was reliably identified between them. I was assured by the designers—in whom I have every confidence—that they used different power amplifier stages, the addition of an input coupling capacitor, a good quality 33μF polycarbonate type, to give protection against excessive DC offsets on non-Audiolab preamps. This introduced a subsonic rooll-off with a -3dB point at around 15Hz it was considered to be too low to be significant.

The results of this double-blind test confirmed the experience of the Audiolab designers, who had decided that the capacitor should be omitted except in cases where essential to block DC.

**PASSIVE COMPONENTS**

For interest's sake, some subjective tests were performed on resistors during the capacitor auditioning. Only a few types were tried, more generic than specific, and only in one application, namely as the 100ohm biasing resistor, for the double-blind test. As reported on by Christopher Breuning a few months back (HFN/RR June 1985). The test cartridge was an Empire van den Hul MC1000 and the preamp an SP-8.

The judgments are arbitrary to some extent, based on the listeners' experience of sound quality 'improvement'. Even if the reader disagrees as to the true meaning of the observation—is it a change or an improvement?—the results do suggest that the resistors differ in their effect on the system's sound quality. Given the minute power and voltage levels involved in the test application, it is highly unlikely that thermal or voltage stress effects—which would result in the nominal resistance being modulated by the signal—are involved.

R1 Make: Holco
Score: 91%
Type: 100μm thick film
Comments: Very small effect; tight, precise stereo and good overall control.

R2 Make: RS Components
Score: 86%
Type: 100μm thick film
Comments: Trace of 'muddy'; slight loss of space; a touch of treble grain and a softer bass.

R3 Make: Roederstein
Score: 84%
Type: 100μm thick film
Comments: Good bass sound, with pleasing depth but a slight grain and 'uzz' in the treble. A slightly 'muzzy' effect in the midrange.

R4 Make: Anonymous
Score: 70%
Type: 100μm carbon film, 1/4W
Comments: 'Zitty' defocused sound; 'founded' and mildly fatiguing; grainy treble.

R5 Make: RS Components
Score: 64%
Type: 100μm carbon film, 1/4W
Comments: Defocused and grainy sound, with loss of bass definition, stereo depth and focus.

We emerged from this brief series of tests feeling that while resistor differences were difficult to identify, significant differences were nevertheless present. The effects may well be different in alternative circuit positions and at different power and voltage levels, but in this application, only the Holco proved capable of loading the cartridge without apparently degrading the sound quality of the SP-8 preamplifier to some extent. The other four resistors were felt to reduce the sound quality sufficiently to make them unsuitable for the circuit in question, and therefore irrelevant. They were therefore omitted altogether.

**OVERALL CONCLUSIONS**

Discussions with the designers and manufacturers of some of the finest audio equipment made today—Conrad-Johnson, Audio Research, Kreil, Counterpoint, DNW, Naim, Sony Esprit, Audiolab and Mission—have revealed an increasing awareness in the industry concerning the role of passive components and the need to select the best possible components for the cartridge irrelevant. They were therefore omitted altogether.
proportion, the success of their products is due to the positive identification of capacitor 'sonic signatures' and the correct or optimum choice of component for each application. The high performance of their products certainly goes a long way towards justifying the contention that capacitors can produce effects on sonics that are directly unrelated to their theoretical performance.

Walter Jung 1, Richard Marsh 1 and John Curl 2,3,4,5 to name but three widely respected designers and electronic engineers, firmly subscribe to the view that capacitors exhibit important sonic differences, despite the views of others 6,7,8. Jean Hiraga was virtually a voice in the wilderness back in the '70s when he described audible differences due to passive components, but much of his pioneering work has since been verified and expanded upon 9,10,11,12,13,14. HFN/RR has rightly been cautious, but in the words of a current slogan 'We're getting there'.

In this article, we will report the results obtained in this article that nominally identical, supposedly good, capacitors do exhibit important sonic differences, which are relevant to high quality amplifier design. It even appears that one capacitor may have as much effect on the overall sound quality as the circuit design itself. Furthermore, the power supply reservoir capacitors affect the quality of the signal, and the addition of a high quality, comparatively low value 'bypass' capacitor can offer a significant change. It is quite surprising that the effect of changing a power supply capacitor can be so readily heard—theoricians will have to do some serious thinking here. To some extent, this provides additional evidence to support the contention, long held by some audiophiles and designers, that the power amplifier mains cabling, supply quality and source impedance may all be heard to contribute to some degree to the ultimate quality of the audio signal as it passes through the system.

It was also fascinating to discover that the inherent signature of a large power supply electrolytic could be detected by using it as a moderate power, speaker coupling capacitor or, through the use of a perfect coupling capacitor between, say, a CD player and an amplifier or a preamp and a power amplifier. Our tests would indicate that even the best electrolytics are some way behind the finest film capacitor. However, a note worthy discovery was the comparatively high quality of a commercial bipolar electrolytic used for loudspeaker crossovers when inserted between pre- and power amp. In general, it comfortably betters the performance of most of the ubiquitous polyester film types.

I have made no attempt in this article to document the electrical and mechanical imperfections of practical capacitors. These are generally well known but have been considered virtually irrelevant to audio applications. The aspects we will be concentrating on are the effects of capacitance and, in particular, I will be looking for some indication of reasons for the differences, using a series of measurements including a modified diode absorption test, as well as the Curl differential pulse analyser in conjunction with Fourier analysis. It would be rewarding to define the optimum specifications for audio quality capacitors—I hope we do it!

WAT THE WORLD NEEDS IS... ‘A £100 integrated tube amplifier!’ (from Kessler), ‘More Mozart on CD from Mitsubishi Uchida’ (from Chocquic): ‘More time’ behind the text in the magazine” (from Art Editor Gash); ‘More copy submitted on floppy disc—and on time!’ (from Production Editor Linda). The subject, of course, should have been: ‘More time’ behind the text. The only plan that the HFN/RR Accessories Club offer, but things were getting out of hand.

Pops pulled himself up from his customary slouch and crumbled the empty can of San Miguel. He? (from Kessler). ‘You think you have a plan. What the world needs is... a moving-coil step-up device with a ridiculously low level of noise, a sensible 20dB or so of gain rather than the exaggerated 22dB that is normal these days. The input impedance is 1000ohms so, true high-end sound quality, and most important, a price under £50’.

The others were awed into silence—except for Kessler (from Chocquic): ‘Tim got on the phone and asked for Tim de Paravicini, the only man in the world who could deliver what Pops wanted, with no questions asked. The transformer, for such it turned out to be, duly arrived, was christened ‘Tim’ (with due respect to Tim’s epoch-making HEAD device and the official HFN/RR Accessories Club hue of black) the Black Head, and was dispatched to Martin Colloms for its verdict.

The Black Head mC transformer

Most commercial mC step-up transformers are either too expensive or offer excessive gain, the latter often leading to compromised performance, as well as an increased possibility of overload with inadequate amplifier m inputs. For the HFN/RR Accessories Club Black Head, transformer wizard Tim de Paravicini came up with a design with an eminently sensible gain of 10, or 20dB, higher. It took him 10 years. The Black Head itself was made from real wood!—already used for the Flux Dumper and the Phase Shunter. The input and output sockets are gold-plated, and the user has to supply a short phone-jack lead to connect it to the moving-magnet input of his amplifier. The nearest commercial equivalent to the HFN/RR Black Head is Made in Japan by Matschi (Lian) and was sold for a while as the Sony HT-10. This is now available as the Ortofon T-5 and also a Glanz model.

I tried the Black Head in my reference system, using it to step up the output of an EMT vhd cartridge to feed my Audio Research SP-6 pre-amp. It was also used with a Linn Trak cartridge and a Rotel 820BX integrated amplifier.

The sound was slightly lightweight—a touch bright but highly controlled over the whole frequency range. Depth and focus of the stereo image were fine, while stage width was well translated. If kept away from large mains transformers, the hum level was satisfactorily low. The Black Head is a good example of its kind with a performance up to a level of some commercial models costing £150.

In the lab, when the Black Head was fed from a 60m sound source and loaded with 60k in parallel with 220pF, the voltage gain was 19.5dB, i.e. fractionally under 10. This should be perfectly adequate for all but the loudest output cartridges, such as some Ortofon. Fed from this source, the frequency response was +0.1, -0.5dB, 10Hz-13kHz; with a lower source resistance and with the load capacitance reduced to 100pF, the upper -0.5dB limit improved to 20kHz. Channel balance was fine at 0.1dB.

Loaded with 100ohms, the input impedance was fine at 500ohms, and when sourced by 100ohms, the output impedance (at 1kHz) was sensible at 2k6. For a nominal 100V output, the distortion was ~95dB at 1kHz, while at normal operating levels, ~100dB (0.001%) should be expected.

On the basis of these test results, I consider the Black Head to be a bargain, with a better performance than the majority of mC inputs fitted to a number of current integrated amplifiers and preamplifiers.

Martin Colloms

4: J Curl, Letter to the Editor, HFN/RR August 1985
5: D Self, Letter to the Editor, Wireless World, April 1984
6: D Self, Letter to the Editor, Wireless World, April 1985
7: P Baxandall, ‘Comment’, HFN/RR May 1985
8: P Baxandall, Letter to the Editor, HFN/RR July 1985
11: JP Moncrieff, IAR Hotline 14, October 1981
14: D Moncrieff, reported on by K Howard and A Gold, Hi-Fi Answers, August 1985
IN THE FIRST CAPACITOR REPORT (October p35) I promised a range of capacitor measurements which I hoped would show up differences beyond the basic parameter of nominal capacitance itself. The article also described the results of a number of listening tests and I hope here to establish relationships between certain measurements and sound quality.

Four tests were chosen: dielectric absorption (DA); electro-mechanical resonance (EMR); nulled error signal (ES); and finally the frequency response of the error signal (FRes). The first, DA, is often mentioned in the literature, and concerns the electric 'memory' of the insulating dielectric of a capacitor. If a charged capacitor is dis- charged through a low resistance for a significant time, say greater than one second, the voltage should remain at zero when the short circuit is removed. In practice, even after prolonged discharge, some voltage returns, this being due to a degree of charge absorption into the dielectric. This is a fundamental flaw in capacitors, and the degree to which it occurs varies with the type of construction. Our tests used the Jung arrangement as described in Audio (February 1980). Here, each capacitor was charged to 1-V for two minutes, discharged via a 1000m resistor for five seconds and the absorption voltage reappearing noted at 10, 20, 40 and 60-second intervals. The quoted DA figure is given as:

DA (%) = V C ('min') x 16.7

The second test is admitted rather arbitrary and concerns the mechanical and piezo resonance properties of capacitors. It has been observed that capacitors emit an acoustic and mechanical output in response to an electrical input. For instance, they are piezo-electric. Furthermore, they will inevitably have a structural self-resonance. This response could colour the sound by putting back energy after the signal itself has passed. To explore these effects, relevant capacitors were fed an impulse from the FFT analyser, amplified to 14V pk, and current limited via a 40m resistor (the test circuit giving -3dB, 45° at 10kHz for a typical 4mF component). The analyser bandwidth was 50kHz. The vibration in the capacitor body was sensed by a very low mass accelerometer, the scaling remaining that of acceleration. Graphs of vibration were taken over a 100Hz - 50kHz span, with log frequency scaling.

The remaining tests, ES and FRes, made use of a high performance differential amplifier designed by Ben Duncan, using John Curl's method (see August p15). Verified by other tests, including DA measurement, a known good capacitor is used as a reference against which to balance unknown test capacitors. The difference signal (generated with a variety of sources from

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<tr>
<td>1 Branded 5pF</td>
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<td>12 UltraCap 4pF</td>
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<td>30 Solid Aluminim 4.5pF</td>
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*With specified capacitance.
C7. This capacitor is clean in the audio range, peaking at 21.5kHz, while on the impulse graph, it is back to normal scaling, the early overshoot now being very narrow, while the secondary overshoot is of long duration. The TF result is also good.

C8. A surprisingly high level of piezo vibration, with the first peak at 9kHz and considerable output above. The impulse test shows another good result with very low error. The narrow visible undershoot is well below audibility. The TF agrees well, displaying a low energy level throughout.

C13. Shows sharp multiple resonances at a fairly high level, the output rising at 10kHz and peaking from 14.6kHz upwards. The second graph shows another different pulsed shape, with a small error but with a slow undershoot.

C14. A typical result for a small electrolytic. The 'wet' construction and outer container block what little self vibration might exist. Note the scaling on the impulse response; 1.65mV compared with the 0.2V div used normally. This electrolytic has huge, complex errors over a timebase extended by approx 20ms. The TF peaks at just -13dBV at a low 150kHz.

C15. While its DA was very good, its EMR was poor, with a strong peak at 14kHz, -50dBV. Top-rated components reach down to -10dBV here. Back to normality with the impulse response, the error is at upper frequencies, and the LF is good. In good agreement with the error on the TF peaks at 5kHz at a moderate -40dBV.

C17. Another model with a promising DA but peaky vibration character.
The finest capacitors have DA values of under 0.1%, low piezo electric effects, with a well damped mechanical self resonance and a low delayed error, the latter combined with a broad smooth character to the response transform of the error function. Different capacitors exhibit differing behaviour with differing sonic flaws. The response display of error function can suggest where the dominant coloring might appear. The time constant of the error pulse may also pinpoint specific problems. Note that the pulse errors displayed occurred in a very short time span – a few thousandths of a second – while the dielectric absorption effect is a much longer-term aberration: 10-60 seconds and longer. The results suggest that electrolytics suffer from a general blurring and specific low-frequency problems, while polyesters have delay problems in the upper midrange, leading to 'nasality', 'glare' and related tonal aberrations. Polypropylene defects occur within a much shorter time-span and are generally much smoother than for other types. The degree of these various effects is partly dependent on the dielectric stress, and this may be reduced by choosing higher voltage ratings than are strictly required. Depending on the application, other parameters such as equivalent series resistance (ESR), self resonant frequency (electrical), series inductance peak current etc, will all also be important. For example, the two Norelec 10,000µF 100V capacitors were very similar on DA, but the Morecroft version has rather better ESR at high frequencies due to reduced inductance. As it happens the best polypropylene capacitors are very good on these parameters too.

C28 A surprise! Tantulums have some mechanical resonance, mild around 9kHz and peaking strongly above audibility. Note the high 2V/dV scaling on the impulse graph; the tangent has large over- and under-shoot. The TF shows a high, broad energy level, just -16dBV

C29 This polyester reads off-scale with the 6kHz resonance at only -44dBV. More nonsense occurs further up the range at a high level. Though claimed high quality, the impulse response shows it to be actually pretty poor, with heavy low-frequency overshoot around -36dBV at 250kHz.

Conclusions

The pulse and noise to music corresponds to the difference in the time domain due to delayed errors in the test capacitor. The error is shown as a direct waveform resulting from a nullled step response and the difference was also obtained using noise to give a frequency response, TF. The latter may give a better idea as to how a particular capacitor might sound by revealing any frequency 'conscioussness'. At this stage the differential set-up could only be used for capacitors in the 0.5 to 10µF range. Vibration measurements were not appropriate for electrolytics due to their 'soft' construction, though interesting results were obtained for the small tantalum capacitor tested. The DA test was fine for all types from 0.5µF upwards, including the 10,000µF reservoirs.

Before proceeding to the test results themselves, there is a correction to be made to the October listening results, as well as a few important additions.

Correction: C19 is a standard Prosec, not to the Morecroft pattern.

Additions, not in ranked order:
C26: 2µF 100V Siemens Polyester (block type), 58% A typical polyester sound.
C27: 4µF, 425V, Ultracap (latest) polypyropylene. Very clean and clear, score 88%. Overall, no obvious aberrations. Transparent, well focused, dynamic. When UC bypassed it achieved a top rating of 94%.
C28: 4.7µF 35V Tantalum (RS) electrolytic. Quite good tonal balance but with an 'artificial' effect, forward and thin with added 'glare'. Emphasised sharpness, some grit in the treble, though the bass was quite good; 62%.
C29: 4µF PMT plastic film (probably polypropylene). Brash, grainy sound, forward thin and toppy – a disappointing result; 58%. On this component the fault may lie with the terminations.
C30: 4.7µF, 35V solid aluminium electrolytic. A phasey, deadened effect lacking dynamics. Loss of space and ambiance, softened bass definition; 59%.
Martin Colloms, following Jean Hiraga's lead, began to investigate the sound quality, electrical and resonance properties of passive components during 1985 for Hi Fi News with a two part study of capacitors printed in October and December issues, HFN 1985. It formed part of research into the sound of amplifiers where it was clearly impossible for 'good' amplifiers to sound indistinguishable, as claimed by several researchers and electronic designers (and still claimed by some), when it was and is possible to show that the necessary passive electrical components used to build them had their own sound quality differences. Related investigations were made into audio cables and resistors, with similar results for audible differences. Largely unreported, investigations into mains transformers, volume controls, plugs and connectors, vibration isolation devices, the design of amplifier casings, methods of printed circuit board support and varieties of supply regulator have been done. There is very little in audio engineering that does not affect sound quality.

A partial review of this material is also included in the Martin Colloms article first published in Stereophile 1992 (HFC Archive A7, 'Pace Rhythm and Dynamics (and Timing)' often misquoted as 'PRaT'!"