CAPACITY FOR THOUGHT

John Linsley Hood looks at audio circuits and tells you where to put your capacitors

Last month I looked at the construction of different types of capacitors and the materials that are used in their manufacture. Now that you've absorbed all that (haven't you . . ?) we can get to grips with their applications in audio circuits.

Circuit Applications

It is practicable to design audio amplifiers without very many capacitors at all and most IC op-amps only have one, used to stabilise the circuit at high frequencies by reducing its HF gain.

In audio circuitry, capacitors will be used as DC blocking elements such as C1 in Fig. 1 to prevent inadvertent DC offsets that occur in early stages of the system from being amplified along with the wanted AC signal and ending up as a very big DC offset at the speaker output terminals.

A similar function is performed by the series capacitor in a negative feedback circuit (C2 in Fig. 1) where 'A' is some kind of gain block (an op-amp or equivalent). The gain of this stage at some frequency where the impedance of C2 is low enough to be neglected is (R2+R3)/R2. However at DC, where the capacitor (if it is a perfect component) is an open circuit, the gain reduces to unity so any DC offset between the '±in' points of the amplifier will not be made worse by the AC stage gain. The corollary to this is of course that the gain of the stage will decrease as the operating frequency decreases and the impedance of the capacitor increases, so it must be big enough.

A further important function is in the decoupling of the supply lines to the amplifier (C3 and and C4 in Fig. 2).

Most amplifier circuitry is designed in the expectation that the ± DC supplies to it will be stable and free of ripple, unwanted signal components or general noise and rubbish. The performance of the amplifier may be impaired — especially in relation to its stability margins, which are very important — if any output signal can find its way back into the signal circuit by way of the supply lines. The easiest way to secure clean smooth supply voltages is in theory to decouple them to a good neutral '0V' line by way of a very low impedance capacitor.

The final circuit positions where capacitors are needed is in time-constant generation circuitry, in tone controls, frequency response shaping circuitry (such as RIAA), LF and HF filters, and HF loop stabilisation functions. Fortunately, in most of these positions the actual capacitance values required are fairly small, so problems of cost or physical bulk are usually minor ones.

Now let us look at these applications and see what characteristics are particularly required.

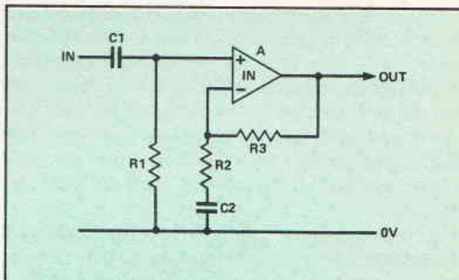

Fig. 1 Capacitors in audio amplification

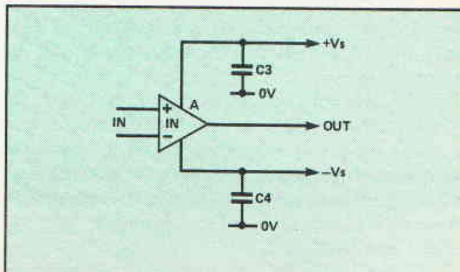

Fig. 2 Capacitors as supply decouplers

DC Blocking

Looking at the circuit in Fig. 1, the important needs are that the impedance of C1 at any valuable part of the audio signal bandwidth should be sufficiently low (in comparison with R1 and the input impedance of the gain block 'A') that the input signal is not attenuated significantly.

For the blocking function to be adequately performed, the leakage resistance of the capacitor must also be very high. Fortunately with modern film dielectric capacitors this can usually be taken for granted.

This might not be true in the case of electrolytics especially if the polarity is inadvertently reversed through careless installation or incorrect interpretation of circuit operating potentials.

Generally, in circuitry with hi-fi pretentions it is well to avoid electrolytics in this position and if necessary rearrange the circuitry so that large capacitance values are unnecessary.

The impedance presented by the other parasitic elements (inductance and series resistance) is unlikely to be significant, certainly in audio use, in comparison with the combined input impedance of R1 and the gain block.

It could also be argued that for hi-fi circuitry the effective capacitance value of C1 should remain constant (especially as a function of the voltage applied across it) so that it does not introduce subtle waveform distortion effects.

Once again, plastic film dielectric capacitors (the so-called 'non-polar' types) are unlikely to suffer from this defect at typical small signal voltage levels to an extent which is detectable. It might though be a problem with electrolytics.

Feedback Path Capacitors

The other DC blocking function is typified by C2 in Fig. 1. Here the problems are greater since circuit constraints are likely to force the use of a relatively low value for R2, and the LF roll-off frequency (the '–3dB' point) occurs where the impedance of C2 ($1/2\pi fC$) is equal in value to R2.

In the past, C2 would have almost always have been an electrolytic type, aluminium or tantalum, but in current practice it is likely that a non-polar component would be employed to avoid any possible 'dulling' of the sound. The values of R3 and R2 would be increased as much as other circuit demands allowed.

The same needs exist here as in the input DC blocking capacitor, but are all greatly magnified because the circuit impedance is usually so much lower so that small changes in series impedance or capacitance value are likely to be much more important.

Supply Line Decoupling

Here the overall need is for the effective impedance to be as low as possible and to remain low over the whole of the frequency spectrum. The preservation of a low decoupling impedance well beyond the limits of the audio range is important for loop stability reasons. Improvements in the purity of the supply lines are usually apparent in the sound quality.

Electrolytic capacitors are usual for this and have a relatively high series impedance by comparison with a non-polar type of the same value. Modern practice is to quote the 'equivalent series resistance' (ESR) of electrolytics in the manufacturer's specification (usually for power supply reservoir capacitor applications).

A low ESR component is usually a good choice if only because it implies that the manufacturers have tried to lessen the inevitable series resistive components by greater care in design or construction. At HF the problem need not be serious, since the main capacitor can always be bypassed by a smaller non-polar type and that if necessary bypassed yet again by a smaller one still.

The reason for this piggy-back activity is that the method of construction of large value bipolar units is likely to lead to higher values of inductance and winding resistances. Indeed for RF bypass use (as in the HF stages of FM tuners) small value disc ceramic capacitors are obligatory because of their very low self-inductance. No wound component would ever be adequate here. Unfortunately disc ceramic devices are usually only available at low working voltages, say 25-30V, a bit low for audio circuitry. Stacked film bipolar types are a good equivalent for audio circuit use.

At the very low frequency end of the passband no capacitor of any sensible size is ever likely to be entirely adequate, and here an electronically stabilised power supply is by far the best answer, especially since if it does its job effectively it will provide an absolute barrier between the operational circuitry and everything on the power supply side of the hardware. This frees the user from worries about whether he ought to replace his mains cable with quarter inch copper bars, or his mains transformer with a filing cabinet sized substitute.

Time Constant Components

Here the overriding need is for accuracy in value and for reasonably low levels of stray inductance, since this could have some effect on the characteristics of filters or feedback circuits. However, spurious inductance effects can normally be ignored for modern components used in sensibly designed AF circuitry, and the effects of stray series winding or loss resistances are likely to be swamped by the general circuit impedances.

Choice In Circuit Applications

In general and bearing in mind the manufacturing details discussed last month, my own order of preference in the capacitor world is polystyrene, polycarbonate, polypropylene and polyester. And I prefer film/foil to metallised foil.

The most critical application, in my opinion, is as the DC blocking capacitor in an NFB loop, though other DC blocking usages must be scrutinised.

Supply line bypass duty requires other qualities and a good quality electrolytic of adequate size and rating bypassed by one or more polyester capacitors of descending values will be quite adequate.

In HF stabilising or time constant duty, polystyrene is the first choice if available in adequate capacitance values. Otherwise use any close tolerance non-polar types.

Above all remember that no single type should always be first choice. It is a matter of 'horses for courses.' ETI