A Power Line Filter for less noise, more music

Described in this article is a basic power line filter of compact design, which is very suitable for use with stereo systems, tape recorders and electric organs. Suppression of switching tones is also discussed.

by IAN POGSON

Recently the author came face-to-face with the problem of extraneous noises coming from a piece of audio equipment. The piece of audio equipment concerned was a large electric organ, and the noises ranged from a loud "plop" down to small clicks and plops from the refrigerator and other domestic appliances. Added to these was the control tone of 750Hz used by the local electricity supply authority for switching purposes.

An investigation revealed that when the player was sitting at the organ, intent on getting the best he could from the insturment, some other members of the household would decide that a certain fluorescent light was no longer required. Switching off the light resulted in a plop which was frightening to the player, to say the least. The particular organ concerned has three audio channels capable of about 50 watts in all, and feeding three husky loudspeakers. The noise coming up from between the player's knees has to be heard to be appreciated! Lesser clicks and plops were not as frightening or annoying, but they did consitiute a nuisance. Similarly the switching tone was not particularly objectionable, but quite noticeable.

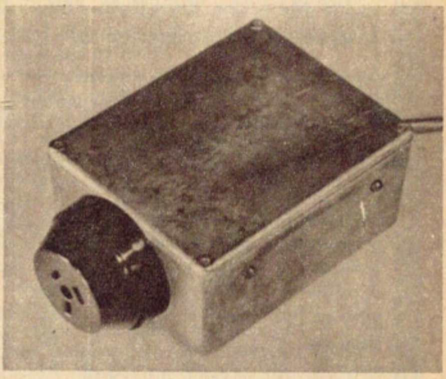
Because of the irritation of these effects, it was decided to try a line filter. A very old but trusty filter was borrowed for trial purposes. When it was put in the power lead to the organ, the results were quite dramatic. The offending plop was reduced to an acceptable level and lesser clicks and plops virtually disappeared. The tone was also reduced a little.

Thus encouraged, it was decided to make up a new filter, using modern techniques to both improve the efficiency and reduce the size as much as possible.

Before we proceed with details of the new line filter, some readers may wish to refer to earlier articles on the subject. The first references on our files date back to January and July, 1953, where a filter was described, followed by comments on combating noise in radio reception. In February, 1960 another line filter was described and this was later incorporated into a composite article in January, 1968, which gave details for aerials which were designed to combat noise in radio reception. Finally, in October, 1969, a heavy duty line filter was described and which was capable of dealing with powers of the order of 1KW.

The last named unit used inductors wound on ferrite aerial rods, and this idea was used as a starting point for our new filter. We reasoned that we could get a large amount of inductance by using ferrite rods and by virtue of the fact that we are only interested in 300 watts or so, a smaller gauge of wire could be used. This means that we could add turns to achieve extra inductance. Furthermore, by reducing the length of the rods and layer winding, we could get a high inductance into a small space.

We started with a ½in diameter ferrite broadcast-band aerial rod, 7½in long, made by Plessey Ducon. This was broken in the centre, and a coil wound on each piece. Each coil consisted of 300 turns, made up of three layers of 100 turns each of 22 B&S emanel copper wire. This results in a coil with an inductance of about 4mH and a DC resistance of 0.7 ohm.



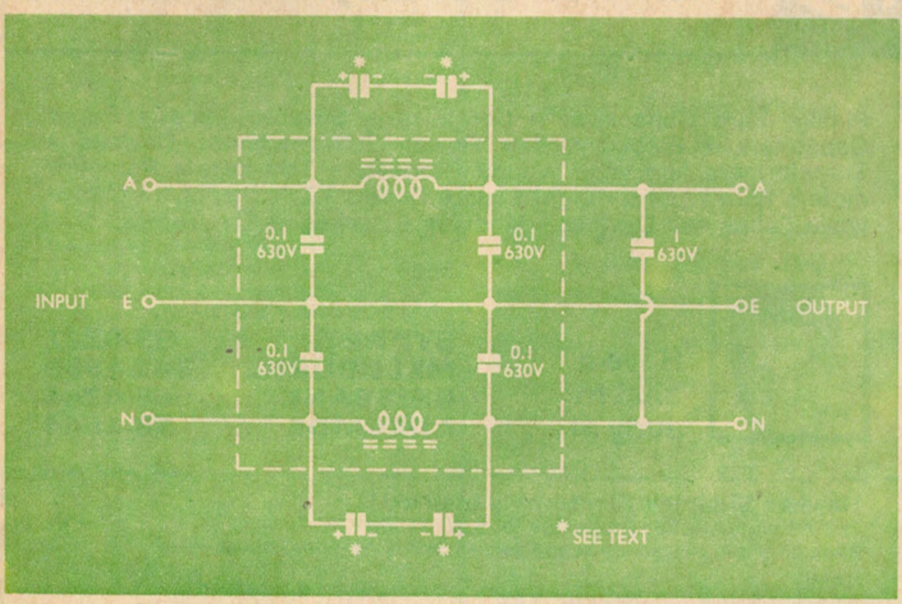
The author's filter, which is housed in a robust aluminium alloy case.

Having made the two coils, a basic line filter was mocked up, using the usual pi configuration in each leg of the line. Capacitors of 0.1uF were used for the trial. Tests soon indicated that this filter was even more effective than the one originally tried. The clicks and plops were further reduced, generally to the point where they were insignificant. The control tone was also down by a useful amount. The initial tests indicated that a line filter using these components would be worthwhile, without any further development.

However the author was not satisfied that the ultimate had been achieved in terms of reducing the control tone, and had a further look at this part of the problem.

Our thoughts turned to some of the matters which were discussed in "Forum", for December, 1969 and June, 1970. The subject of control tones was discussed at some length, and designs given for filters specifically designed for reduction of the tones. Readers who wish to check further, may refer back to these two items. Basically the circuits consist of an L filter, with a parallel resonant circuit at the frequency of interest, in series with the line. The shunt leg in its simplest form consists solely of 1uF capacitor. The more elaborate approach uses a series resonant circuit at the same frequency.

The inductor in each case should be about 30mH, for a tone frequency of 1050Hz. Our quest for a suitable inductor revealed that the Ferguson type CF435, originally made for use in our 1959 Karset, has a nominal inductance

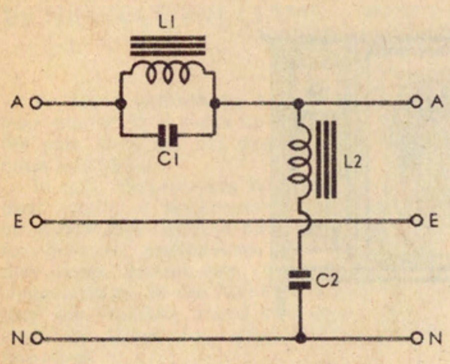


The circuit for the filter unit, with the basic section within the dashed line rectangle. The inductors are wound on ferrite rod sections.

of 30mH, a DC current carrying capacity of 1.25 amps and a DC resistance of 1.4 ohms. This seemed to be worth a trial, although the current carrying capacity would be rather restrictive.

Accordingly, a filter with parallel and series resonant elements was mocked up and tried. The tests showed that the tone was reduced quite markedly but it was still in evidence. It would appear from this and experiments other staff members have conducted along similar lines, that some of the offending tone gets into the amplifier by a route other than directly through the mains supply. Accordingly it would seem that further searching for a better filter for the line would not be worthwhile.

In spite of this relative setback, we felt that the efforts so far were worthwhile and further checks should be made. Suspicious that the inductor in series with the line would not be large enough for some heavier loads, say 300 watts or so, we actually ran the organ with the filter in circuit for some hours and



The circuit of the special L-section filter to suppress control tones.

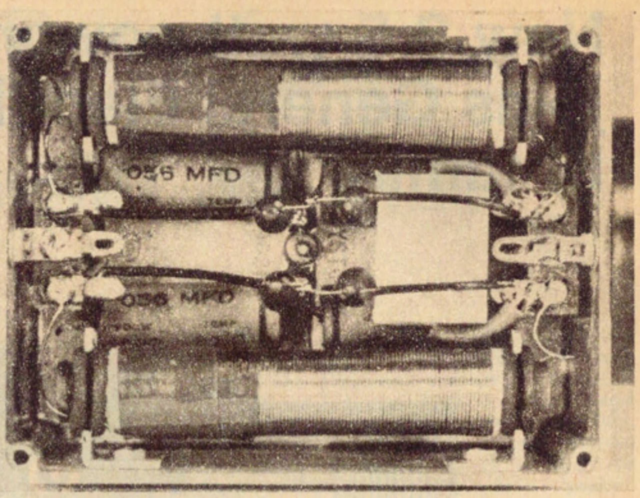
with an ambient temperature of about 75 degrees F. This test showed that the inductor in the series resonant leg remained cool, as it should with no significant current flowing through it. However, the inductor in the parallel resonant circuit, with the full current load flowing through it, became quite warm. Although it was not overheated, we considered that this inductor was not capable of doing the job with the load we had in mind.

Although we abandoned this approach as the solution to our problem, there is no reason why readers who have a load of say, less than 200 watts, should not try it for their particular purpose. Further details will be given as a guide to capacitor values later on.

It may be noticed that the circuit of the conventional line filter is enclosed within dotted lines. We returned to this point and as we have already mentioned, this does give some attenuation of the control tone, but it leaves quite a lot to be desired. Our first addition was to place a 1uF capacitor across the output of the line filter. This effected some improvement in attenuation, but there was still room for improvement.

Earlier, we mentioned that our coils for the line filter were wound on ferrite rods and with the idea of getting as high an inductance as possible. With 4mH, we considered that this amount of inductance could be resonated to either 750 or 1050Hz. Resonance at 750Hz would be achieved with about 11uF. This means that we had to resort to electrolytic or tantalum capacitors and as these are polarised, two 22uF units placed back-to-back were required to do the job. Although the LC ratio left something to be desired, it was worth a trial.

The interior of the author's unit, which includes the 750Hz tone filter components. These may be omitted if not required, as noted in the text.



With 11uF across each of the two coils, a check with the audio generator showed that a worthwhile amount of attenuation had been gained. This arrangement under test, as near as we could judge, seemed to be as good as the special L filter tried earlier. Finally, we added a series resonant circuit using a CF435 inductor across the output. But this had little or no apparent effect.

In short, the basic line filter, with 1uF across the output and 11uF capacitor across the two coils, gave us very close to the maximum attenuation, and we decided to settle for this. However, we feel that this may be the story only for this particular case, so that the whole problem is still wide open for individual experiment. Readers may therefore wish to check the various ideas to determine the best solution for their own particular problem.

Construction of the basic filter is quite straightforward. As mentioned earlier, the two coils are wound each on half a ferrite aerial rod, made by Plessey Ducon. We used a rod ½in in diameter and it would be best to stay with this size, but if supplies should be difficult to obtain, then the 3/8in diameter rod may be used instead. This applies if only the basic filter is to be made. However, if it is desired to tune the coils to either 750 or 1050Hz, then with the smaller rod the inductance will be less and a higher value of capacitor will be needed.

Having obtained a rod, the first task is to divide it into two equal parts. The centre is marked accurately and a shallow groove is cut right around the rod, using a three cornered file. The rod is then held in a vyce, with the groove just slightly above the jaws. A sharp tap with a hammer should then break the rod in the right place, although one will be very lucky to get a clean right angle break. Fortunately, this is not important.

Before commencing to wind the coil, a layer of insulation should be placed over the rod. We used a piece of stout brown paper, sufficient to give one slightly overlapping turn around the rod, 3in long and centred on the rod. The start of the winding is held in place with a loop of insulation tape, so that the first and subsequent turns pass over the tape to hold it in place. Wind on 100 turns and then cover the winding with a layer of paper. Continue winding and then cover this layer with another piece of paper. The third layer of 100 turns is added, the finish being held in place with insulation tape.

Having wound both coils, as part of the method of mounting, we slipped a rubber grommet over each end of the rods and pushed them up close to the winding ends. The start and finish leads were anchored by running them between the rubber grommet and the rod. The flying leads, when cut to length, are connected to the appropriate terminations later on.

The complete filter is housed in an

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Eddystone diecast box 4-5/8in x 3-5/8 in x 2 3/16in. The disposition of the various components may be seen from the picture. The two coils are held with a bracket at each end. We made up brackets from 16 guage aluminium, each measuring 5/8in x 1-1/8in, with a ½in foot. Each bracket has a hole in the foot for mounting to the box and a "U" shaped slot of a size such that the rubber grommet is a neat fit into it.

Instead of a 0.1uF capacitor for each of the four positions shown in the circuit, we used two .056uF 1,000V working paper capacitors. These happened to be on hand but standard plastic capacitors rated at between 630 and 1,000 volts working, are quite suitable.

At each end of the box, we provided a three tag strip for input and output terminations. The input cable, with a 3-pin plug attached, is brought through a grommeted hole at one end. The output at the other end of the box is via a standard 3-pin outlet socket. The socket is screwed to the end of the box and three clearance holes are provided for leads between the socket and inside the box. The four 0.1uF capacitors are fitted under the coils and near the bottom of the box. Line terminations are to the tag strips and the earth connections are to two solder lugs under a screw at the centre of the bottom of the box.

This is all that is necessary for the basic filter and the job is complete if you have no problem with control tones. For the full unit, the 1uF capacitor across the output actually consists of two 0.47uF 630V working plastic capacitors in parallel. The 11uF units across each coil which may also be seen in the picture, consist of two 22uF, 25VW tantalum capacitors wired back-to-back. Care should be taken to ensure that the correct polarity is observed, as shown in the circuit. Although we used and show 25 VW capacitors, these are actually pre-production samples and 22uF 3VW units will do the job.

Having added these capacitors to the basic circuit, it may seem that we have introduced an anomaly. The purpose of the inductors is to offer as high an impedance as possible to high frequency components, and so combat noise pulses. We have subsequently added a high value of capacitance in shunt with each of these coils, and it may seem that this would pass the high frequency components and so defeat the purpose of the filter. In practice however, there is sufficient capacitance across the line, so that the noise is still effectively attenuated.

Although many readers should be interested in the control frequency of 750Hz, others may be interested in the alternative frequency often used, which is 1050Hz. Whereas 11uF is required across each coil to resonate at 750Hz, a value of 5.6uF is required for 1050Hz. This latter value is not so readily obtainable, with two units connected back-to-back. However a pair of 12uF 3VW tantalum capacitors should be close enough. Readers with a capacitance bridge available may be able to select the correct values, but in practice, the resonance point is fairly broad and no problem should arise.

We have shown the circuit for the special L filter specifically for use in combating the control tone problem. As we mentioned earlier, we tried an iron cored inductor of approximately 30mH, type No CF435, which is made by Ferguson Transformers. These are used for both L1 and L2. C1 and C2 should be 1.5uF for 750Hz and 0.765uF for 1050Hz. These values may be made up by connecting suitable values in parallel. C2 must be rated at least to 630V DC working, but C1 may be rated somewhat lower, as the line voltage does not appear across it. Plastic types may be used for each of these positions.