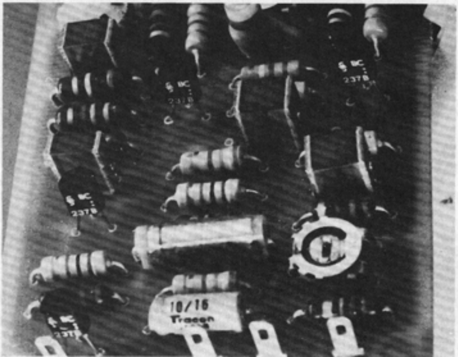
elektor „sonant" loudspeaker system

An earlier article explained the operating principle of the electronic loudspeaker. It was shown that this approach enables a woofer in a relatively small enclosure to provide really good reproduction quality from 40 Hz upwards.
The second step is to describe a complete system, using active crossover networks, based upon the electronic loudspeaker used as a woofer. The system provides unusually good reproduction quality for its modest size and low cost.

An electronic woofer can be designed to have a flat frequency response curve beginning at 40 Hz – or an even lower frequency if desired. This flat response will normally be maintained up to about 400 Hz. Above this frequency it will be necessary to apply additional corrections, which are dependent on the loudspeaker used, the size and shape of the enclosure (and the loudspeaker's position on the front) – and even the position of the enclosure relative to room boundaries.

The simplest design choice would therefore seem to be an application of the electronic loudspeaker to the woofer-range, with reproduction of the mid- and treble ranges by normal units.

Such an approach makes it very desirable to use a separate driving amplifier for the woofer, with crossover networks ahead of this amplifier. The mid- and treble ranges can then be handled by one or two smaller amplifiers, for two- or three-way systems respectively.



Two-way system

The so-called two-way system provides a simple solution which can nonetheless produce excellent results. The block diagram for this is shown in figure 1. The 'crossover' frequency chosen is 340 Hz. The electronic woofer reproduces the range 40-340 Hz, while a separate 10-watt amplifier takes care of the remainder of the frequency range.

Two preset potentiometers, inserted in the circuit ahead of the crossover networks, enable the correct loudness balance to be set up. The adjustment is best done by ear, preferably with the system installed in its working location. In this way the inevitable differences between the efficiencies of the various loudspeaker-drivers used can be equalised.

Care must be taken to connect the two drivers in the correct phase-relationship. The woofer is operated with the 'plus' terminal – the terminal which, when driven positive, causes the cone to move outwards – connected to the 'hot' power-amplifier terminal. The mid-high-range driver is then connected with its 'plus' terminal to chassis, i.e. the 'wrong way around'. On many loudspeakers the 'plus' terminal is identified by the maker, by means, for example, of a red dot.

Three-way system

The three-way system is built up according to the block diagram given in figure 2. The electronic woofer operates as before, for frequencies up to 340 Hz. A second amplifier handles the range 340 to 4800 Hz., while a third unit operates at frequencies above 4800 Hz. This may seem to be the expensive way of doing things; but in practice the additional lower-power amplifiers often turn out to be less expensive than conventional crossover networks. In any case the results are usually better, while the level-balance between the high- mid- and bass-loudspeakers can be very conveniently obtained by adjustment of the three preset potentiometers.

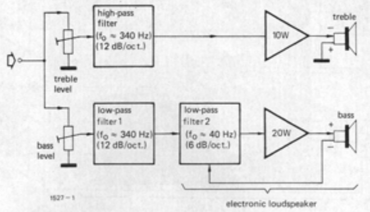
Once again, attention must be paid to correct relative phasing of the drive-units. This is also shown in the block diagram.

The crossover networks

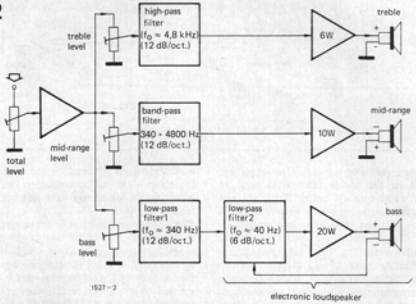
The crossover networks for the two-way system are built up according to figure 3; the three-way circuit diagram is given in figure 4. The circuits are simple, to the point of being primitive, being cascades of passive RC-networks, buffered by means of emitter-followers. Reliable, stable and predictable. Furthermore the two arrangements are so similar that both can use the same printed circuit board. For the two-way system all that is required is a single printed circuit board, with the component layout shown in figure 6.

The three-way system circuit requires two of the boards. One of these is laid out according to figure 7, for the mid-range and treble channels. The other is laid out according to figure 8, with the circuits for bass reproduction via the electronic loudspeaker. This latter p.c. board also includes an input buffer (T_1).

1



2



3

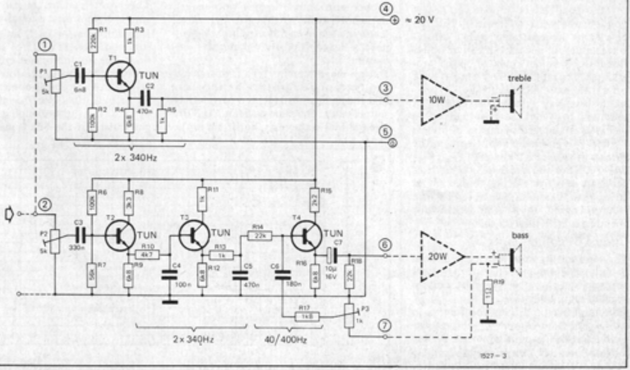


Figure 1. Block diagram of the two-way system.

Figure 2. Block diagram of the three-way system.

Figure 3. Circuit diagram of the two-way system. The motional feedback in the bass-channel is adjusted by means of P_3; the level-adjustment presets P_1 and P_2 enable the correct loudness-balance to be obtained between bass and treble channels.

Parts list for figures 3 and 6

Resistors:

R_1	=	220K
R_2, R_6	=	100K
R_3, R_5, R_{11}, R_{13}	=	1K
R_4, R_9, R_{12}, R_{16}	=	6K8
R_7	=	56K
R_8	=	3K3
R_{10}	=	4K7
R_{14}, R_{18}	=	22K
R_{15}	=	2K2
R_{17}	=	1K8
R_{19}	=	1 Ω
P_1, P_2	=	5K (preset)
P_3	=	1K (preset)

Capacitors:

C_1	=	6n8
C_2, C_5	=	470n
C_3	=	330n
C_4	=	100n
C_6	=	180n
C_7	=	10µ/16V

Transistors T_1 to T_4: TUN

Parts list for figures 4, 7 and 8

Resistors:

R_1, R_{101}, R_{106}	= 220k
$R_2, R_6, R_{102}, R_{107}$	= 100k
$R_3, R_4, R_9, R_{12}, R_{16}, R_{104}, R_{109}, R_{110}, R_{112}, R_{113}, R_{116}$	= 6k8
R_7	= 56k
R_8, R_{108}, R_{111}	= 3k3
R_{10}	= 4k7
$R_{11}, R_{13}, R_{103}, R_{105}, R_{115}, R_{118}$	= 1k
R_{14}, R_{18}	= 22k
R_{15}	= 2k2
R_{17}	= 1k8
R_{19}	= 1 Ω
P_1	= 50k (preset)
P_2, P_{101}, P_{102}	= 5k (preset)
P_3	= 1k (preset)

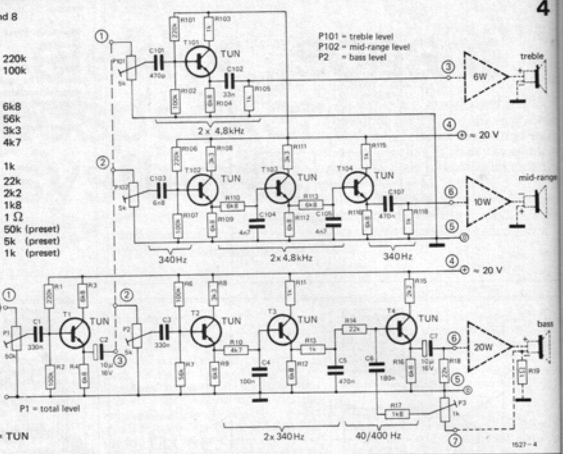
Capacitors:

C_1, C_3	= 330n
C_2, C_7	= 10µ/16V
C_4	= 100n
C_5, C_{107}	= 470n
C_6	= 180n
C_{101}	= 470p
C_{102}	= 33n
C_{103}	= 6n8
C_{104}, C_{105}	= 4n7

Transistors:

T_1 to T_4, T_{101} to T_{104} = TUN

4



Setting-up procedure

The adjustment of the electronic woofer – in either arrangement – is made by means of the preset potentiometer P_3. This is slowly turned up from zero position to the point at which the system starts to oscillate (howl), and then turned back until oscillation just ceases.

Some loudspeakers have inferior magnetic systems in which the degree of electro-magnetic coupling varies during the drive-coil throw. An adjustment made as above can then give rise to a kind of 'after-pong' effect (if once you hear it you'll know what we mean!). This can be clearly demonstrated with a square-wave input; but of course it can be objectionable on some kinds of music programme. The remedy is very simple: back off a little more on preset P_3.

In the two-way system, the balance of loudness between the bass and treble channels is adjusted by means of presets P_1 and P_2. The same adjustment in the three-way system is made with P_{101}, P_{102} and P_2. Turn the preset which controls the least sensitive channel to maximum, then adjust the other(s) until the balance 'sounds right'. It is well worthwhile spending a little time on this.

Choice of components

The components from which this system is built up – the amplifiers, drivers and the enclosure – have to meet certain specific requirements.

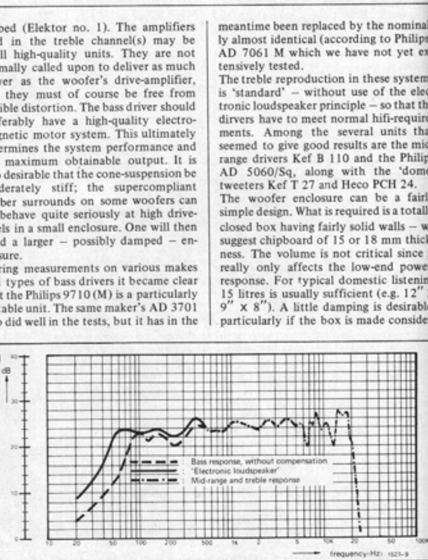
The amplifier used with the electronic woofer must be completely and unconditionally stable, even when its output is short-circuited. The prototype systems used the 'Equa amplifier' previously described (Elektor no. 1). The amplifiers used in the treble channel(s) may be small high-quality units. They are not normally called upon to deliver as much power as the woofer's drive-amplifier, but they must of course be free from audible distortion. The bass driver should preferably have a high-quality electromagnetic motor system. This ultimately determines the system performance and the maximum obtainable output. It is also desirable that the cone-suspension be moderately stiff; the supercompliant rubber surrounds on some woofers can misbehave quite seriously at high drive-levels in a small enclosure. One will then need a larger – possibly damped – enclosure.

During measurements on various makes and types of bass drivers it became clear that the Philips 9710 (M) is a particularly suitable unit. The same maker's AD 3701 also did well in the tests, but it has in the meantime been replaced by the nominally almost identical (according to Philips) AD 7061 M which we have not yet extensively tested.

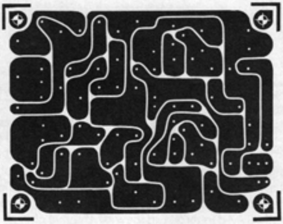
The treble reproduction in these systems is 'standard' – without use of the electronic loudspeaker principle – so that the dirvers have to meet normal hifi-requirements. Among the several units that seemed to give good results are the mid-range drivers Kef B 110 and the Philips AD 5060/Sq, along with the 'dome' tweeters Kef T 27 and Heco PCH 24.

The woofer enclosure can be a fairly simple design. What is required is a totally closed box having fairly solid walls – we suggest chipboard of 15 or 18 mm thickness. The volume is not critical since it really only affects the low-end power-response. For typical domestic listening 15 litres is usually sufficient (e.g. 12″ × 9″ × 8″). A little damping is desirable, particularly if the box is made consider-

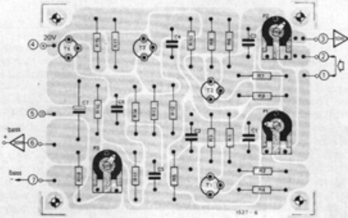
9



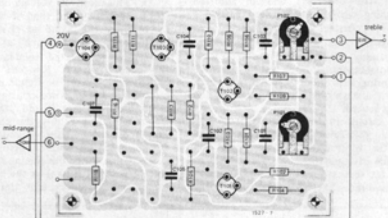
5



6



7



8

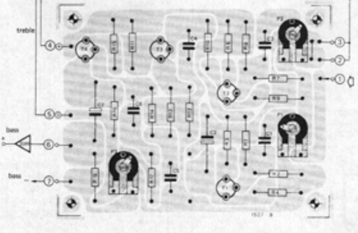


Figure 4. Circuit diagram of the three-way system. P_3 is once again used to correctly set up the bass-channel motional feedback; loudness-balancing is done by adjusting P_2, P_{101} and P_{102}. P_1 provides an additional total-level adjustment, which can be convenient when setting up a stereo pair.

Figure 5. The universal printed circuit layout for all filter circuits.

Figure 6. Components layout for the single p.c. board used with the two-way system according to figure 3.

Figure 7. Component layout for the mid-range and tweeter channels of the three-way system (figure 4).

Figure 8. Component layout for the bass-channel and buffer stage as used in the circuit of figure 4.

Figure 9. Result of measurements (total radiated power) on a typical three-way system.

ably larger than 15 litres. This will usually arise if one wants an extended power-response. Damping may in any case be needed with drivers having limited magnetflux (to help eliminate the 'after-pong' effect). A 20 mm thick pad of glasswool, mounted by means of laths at a random angle through the centre of the enclosed volume – not parallel or close to the walls – will do the trick.

Conclusion

Application of the electronic loudspeaker-compensation described here – actually a form of 'motional feedback' – can enable excellent results to be obtained with a relatively small woofer-enclosure. The curves in figure 9 are the results of measurements made on a typical system, with and without the compensation operative.
The only real objection to this approach is the fact that it requires fairly critical adjustment for best results. This difficulty would be considerably lessened if a bass-driver fitted with a properly-designed and reliable feedback-transducer were to become generally available. The transducer could deliver a signal proportional to the cone's displacement, to its velocity, or – preferably – to its acceleration. One recently-introduced commercial system (Philips) is designed around just such a woofer-accelerometer combination.
As a final remark we note that a loudspeaker operating with motional feedback forms part of a control-loop which includes the power amplifier. It is obviously desirable to install this amplifier in the loudspeaker cabinet, or the fact that the feedback signal is carried by the same leads which deliver the drive power means that the system will require re-adjustment every time the lead length is changed! ■