# TECHNICAL NOTE 156

## 70 + 70 W ACTIVE LOUDSPEAKER SYSTEM USING MONOLITHIC INTEGRATED CIRCUITS

by P. Antoniazzi and L. Crespi

## INTRODUCTION

The most common method to drive an HiFi speaker system is to use a wideband power amplifier featuring a frequency response flat over the whole audio band.
In most cases, the audio signals of the two individual channels (right and left) are split between woofer and tweeter (two-way system in fig. 1) by using passive LC crossover filters.
Less frequently, three-way systems (woofer, midrange and tweeter, as per fig. 2) or even four-way or five-way systems are used. This solution has been proven, so far, most simple and functional with respect to the requirements of both box and amplifier manufactures and users. Moreover, HiFi loudspeaker technology has resulted in the last years in a considerable reduction in the dimensions of the enclosure while maintaining high quality.
As far as power amplifiers are concerned, they changed from tube to power discrete components and now to thick-film «power packs», while monolithic power amplifiers, which are definitely cheaper in cost, have not found wide spread applications in HiFi, so far, because of their low power and a certain mistrust by designers.
Now, at the beginning of the 80's it can be affirmed that not only monolithic power devices have obtained a passport to HiFi, but fully monolithic solutions even present some important advantages with respect to the conventional models.
These advantages are described in the following paragraphs.

*Fig. 1 - Typical two way system for HiFi*

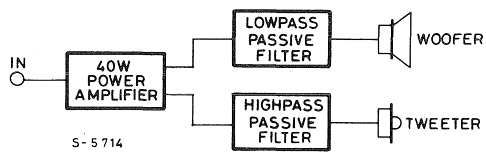
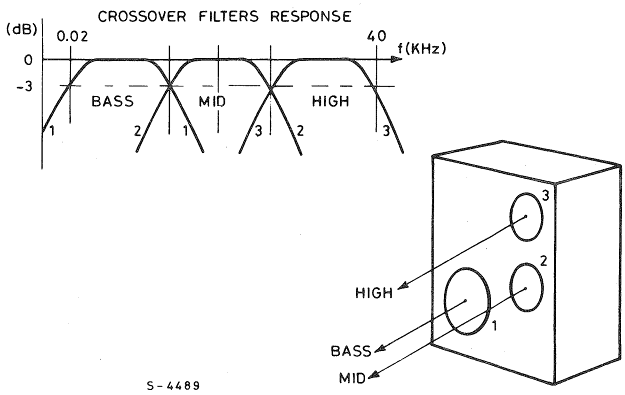


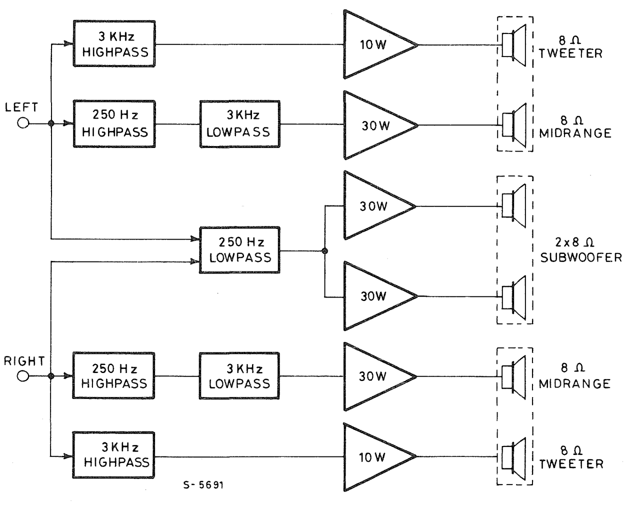
*Fig. 2 - Three way box with crossover filters response*




## HiFi SYSTEM FOR THE 80's

A slow, but inevitable revolution in the audio system field has been started by the imminent introduction of digital 16 bit PCM audio discs (DAD) and by the more and more frequent use of noise reduction techniques (compressors-expandor as CX discs, DBX, etc.): in fact, the most outstanding features of DAD's (dynamics = 96 dB, response dc to 20 KHz, distortion less than 0.03%) will only be fully appreciated if preamplifiers, amplifiers and loudspeaker boxes will have their performance correspondingly improved. The first thing which is mandatory to do in order to improve the present solutions is to implement active multiway systems, i.e. to separate not only the speakers (woofer, midrange and tweeter), but also the amplifiers. With such a configuration the power levels required for the individual amplifiers are lower, and can be provided by the monolithic power integrated circuits presently available.

*Fig. 3 - 70+70W Active loudspeakers system using only monolithic ICs*



A block diagram of a demonstrative solution implemented by SGS is shown in fig. 3; the performance of this solution (measurements and listening) exceed those of a typical HiFi installation. The circuit uses 10 low-cost monolithic power amplifiers in total and the effective output power (pink noise) is 70 + 70W rms.

A number of benefits are obtained by active multiamplification:

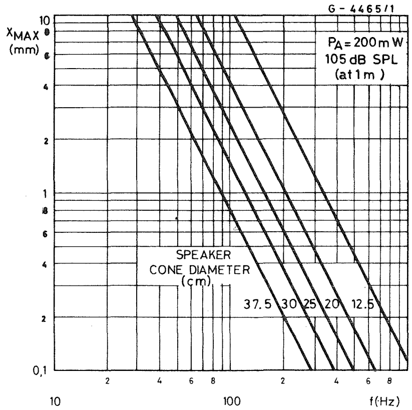
- reduced power level required to the individual amplifiers, sound power levels (SPL) being equal
- substantial reduction in intermodulation distortion and modulation distortion (each power amplifier is required to handle only a relatively narrow range of frequencies).
- complete separation of the ways (if any amplifier is affected by distortion or clipping, the other channels are unaffected).
- protection of tweeters (since the amplifiers are separated, high power harmonics generated by low frequency clipping can not damage the delicate tweeters)
- low cost, thank to the use of monolithic power amplifiers

An added advantage is that as a consequence of connecting each speaker directly to its own amplifier, damping of the voice coil is not influenced by frequency dependent impedance variations in the crossover network.

In the proposed application (using a subwoofer) normally another substantial advantage is in that one of the two boxes optimized in order to have a 3 dB low frequency cutoff of 40 to 80Hz (consequently, a large size box) is eliminated.

As a matter of fact, in a system using subwoofer, one only box with appropriate dimensions (60 litres) plays back frequencies from 30 to 250Hz, practically without stereo effects, while frequencies from 250Hz and 20 KHz are sent to two stereo «satellite» boxes with very small dimensions, which are consequently very easy to locate in the room.

*Fig. 4 - Speaker displacement ($X_{MAX}$) Vs. frequency*




The cone displacement, a determining factor for distortion (see fig. 4 for a sound pressure level of 105 dB), is reduced so as to make the use of small speakers (mini-woofers) possible.

This improves the transient response and extends the range toward high frequencies.

## THE SUBWOOFER SYSTEM

The proposed system uses one only central box, called «subwoofer» and designed for two loudspeakers, in order to achieve an higher SPL (Sound Pressure Level) with low distortion.

In our case, the so-called «acoustical push-pull» configuration has been adopted, with two 10" (25 cm) loudspeakers, so as to reduce the 2nd order distortion by 15 to 20dB. Naturally, the classic and cheaper solution using one only 10" or 12" loudspeaker can be used, provided that an «audible» impairment in performances is accepted.

The power sent to the subwoofer is higher than 60W and it is obtained by means of two bridge-configured amplifiers, using TDA2040 power ICs.

The distortion is typically less than 0.01% thanks to the very high feedback factor and to the total absence of dynamic distortion problems in the frequency range in question.

Two identical amplifiers (30 + 30W) drive the midranges (12 cm miniwoofers) contained in the stereo «satellite» boxes.

In this frequency band too, distortion and TIM of the IC amplifiers have values so low as to be submerged in the noise.

The «dome» tweeters which complete the satellite boxes (example in fig. 5) are individually driven by only one TDA2030A, which supplies a power of approximately 10W with d = 0.02%.

*Fig. 5 - Example of minibox covering the frequency range from 250 Hz to 20 KHz (internal volume 3 to 10 $dm^3$)*

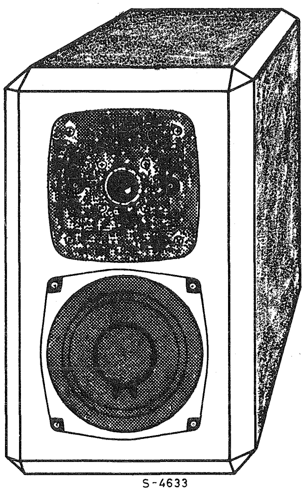
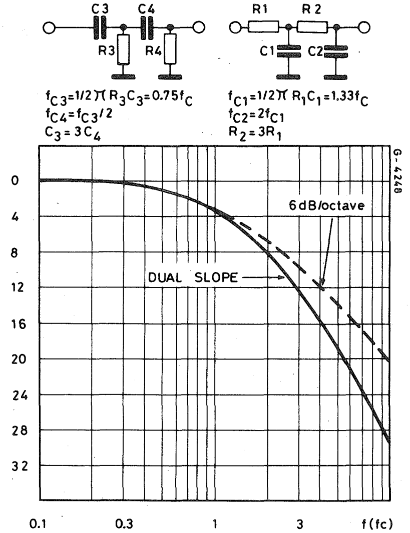


*Fig. 6 - Design of simple dual-slope filters*




The active filters are implemented by using the high quality dual operational amplifier TDA2320A.
Various types of filters can be used in crossovers. Bessel filters are particularly useful as a results of their well known phase linearity and good transient response.
Unfortunately, the frequency response variation of a Bessel filter in the crossover region is too gradual for some loudspeakers.
A good compromise seems to be the Butterworth filter since Chebychev filters, although they offer excellent out of band attenuation, are unsuitable because of their impedance, phase and transient response.
For a simple solution to the crossover filters problem see also Ref. 3 (P. Antoniazzi, A. Hennigan, Dual-slope filters optimize speaker's crossover response, Electronics, June 5, 1980).
The simple «dual-slope» filters (see fig. 6) devised by SGS, gives 12dB/octave beyond the crossover zone without the «hole» at the crossover frequency caused by 12dB/octave Butterworth, because at the crossover frequency the phase shift is only 60°.

*Fig. 7 - Active crossover filter for midrange amplifiers (2nd order Bütterworth 250 Hz high - pass and 3rd order Bessel 3 KHz low-pass)*

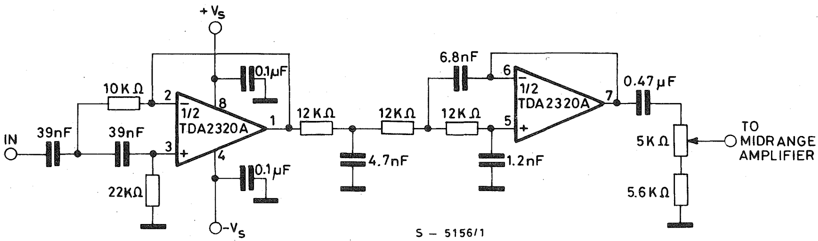
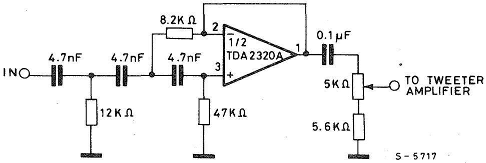
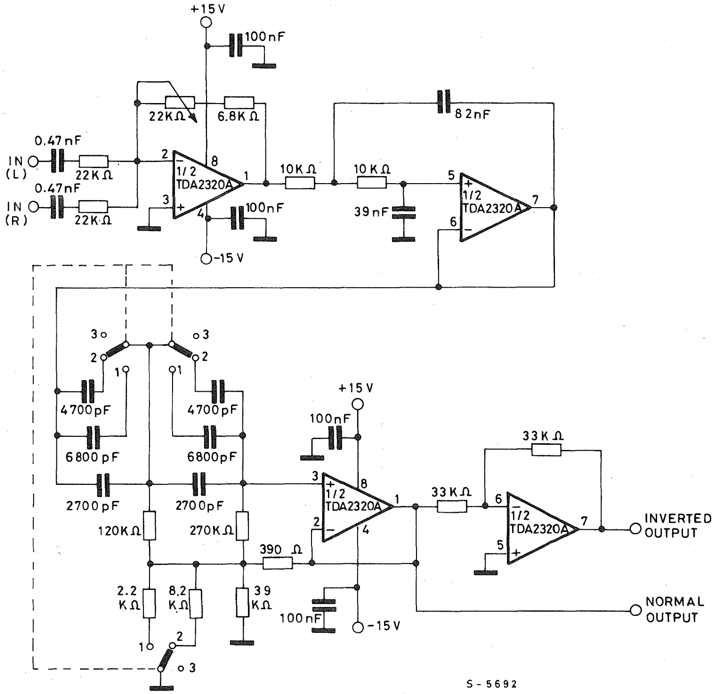



*Fig. 8 - Active 3 KHz crossover filter for tweeter amplifiers (3rd order Bessel high-pass)*




The circuit diagrams of the filters relevant to the stereo paths are shown in figs. 7 and 8, while fig. 9 shows the low-pass filter of the subwoofer and the equalizer used to further compensate for the loudspeaker drop between 30 and 80 Hz.
In fact the falloff in sound pressure level (if permitted by maximum excursion of the cone) will therefore be compensated increasing the output power by equalization.
The frequency response at 1 metre from the speaker system measured in the room is a good starting point for equalization. The circuit shown in fig. 9 is a simple and good equalizer. It is a 12dB/octave Butterworth high-pass filter with damping control to obtain the responses of fig. 10.
The measured acoustical response is practically flat down to 40 Hz. The sound performances of the system in a partially absorbing environment to reduce the early time reflections (see also in the appendix) are of very high quality.
The advantage of active systems in handling more signals at different frequencies (music) should be specially emphasized.
As a matter of fact, let us suppose to send to the system using a subwoofer two signals at 100Hz and

*Fig. 9 - Subwoofer low-pass filter and equalizer*




400Hz respectively, both with an RMS power level of 30W (44V peak to peak on 8 Ohms); these signals are normally amplified by the respective distortionless channel. The photograph in fig. 11 shows how the peak to peak voltage (44V) relevant to the individual signals (100 Hz or 400 Hz) would become twice (88V) and the power four times higher (120W), if the signals were handled by one only wideband amplifier.
In our case, 30 + 30W would be equivalent to 120W!

*Fig. 10 - Frequency response of the filter equalizer circuit of fig. 9*

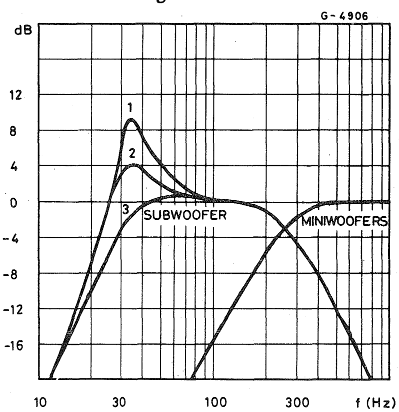
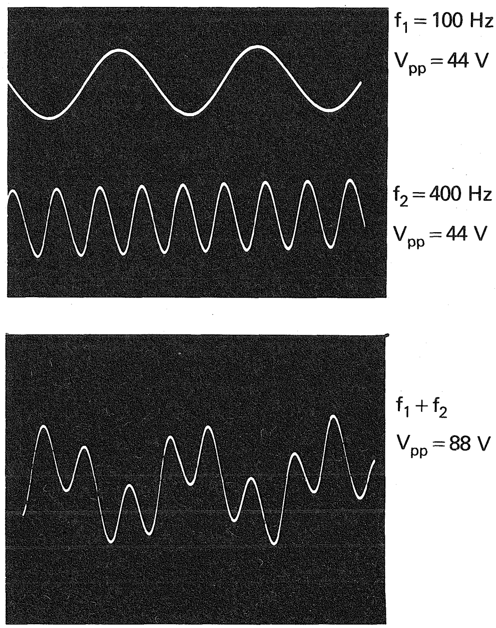


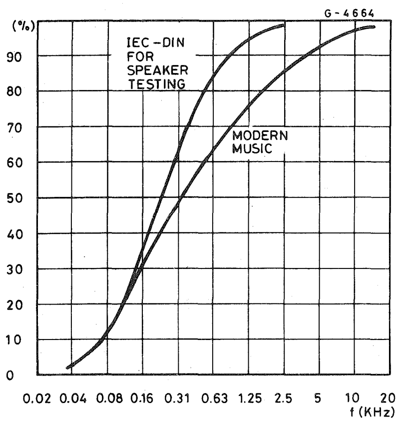

*Fig. 11 - Single tone and multitone output of a power amplifier*



## PRACTICAL AMPLIFIERS

Multiway loudspeaker systems provide the best possible acoustic performance since each loudspeaker is specially designed and optimized to handle a limited range of frequencies.
In order to maintain a frequency response flat over the HiFi audio range, the band covered by the individual loudspeakers must overlap slightly. Unbalances between the loudspeakers produce unacceptable results, therefore it is important to make sure that each unit generates the correct amount of acoustic energy for its segment of the audio spectrum. In this respect, it is also important to know the energy distribution of the music spectrum, in order to determine the cut-off frequencies of the crossover filters. This can be obtained by means of the diagram in fig. 12, which shows the distribution of the music energy versus frequency, according to the old DIN standards (basically classic music) and according to a most recent evaluation (modern music).

*Fig. 12 - Power distribution vs. frequency (Music)*




The diagram clearly shows that the 95% of power received by a loudspeaker is below 7 KHz. Even considering pop music and modern synthesizers, only 5% of music power is normally required above 7 KHz. It is interesting to note that the transition frequency, i.e. that frequency below and above which 50% of the music power falls, is a little higher than 300 Hz. It is consequently easy to evaluate the power level necessary for the individual amplifiers.
For a system of the type proposed in fig. 3 ($fC1 = 250$ Hz, $fC2 = 3$ KHz) and with an overall power level (pink noise) of approximately 70 + 70W, one obtains:

$2 \times 70 \times 0.44 \cong 2 \times 30W$ (subwoofer)

$2 \times 70 \times 0.44 \cong 2 \times 30W$ (midranges)

$2 \times 70 \times 0.12 \cong 2 \times 8.4W$ (tweeters)

*Fig. 13 - 32W Bridge amplifier with split power supply*

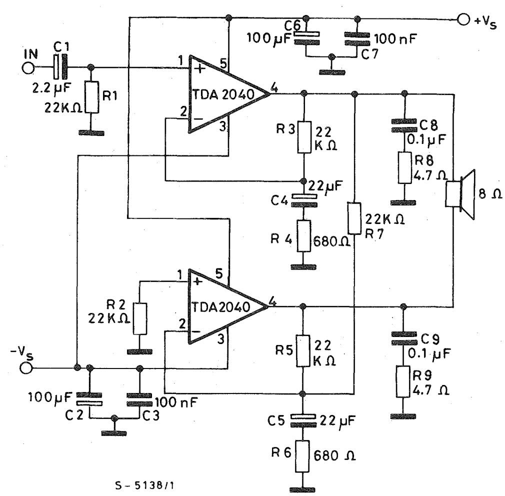
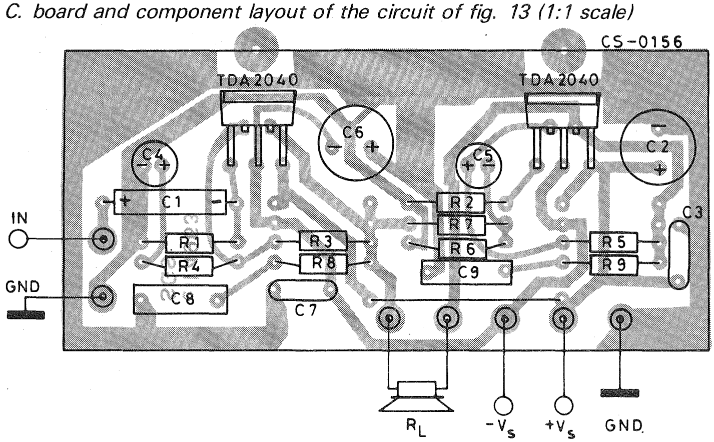



*Fig. 14 - P.C. board and component layout of the circuit of fig. 13 (1:1 scale)*



As already mentioned, these power levels can be obtained by using two types of SGS monolithic power amplifiers. Two bridge amplifiers using two TDA 2040 (fig. 13 and 14) capable of handling more than 40W at clipping and 32W nominal with very low distortion on 8 ohms are used for the subwoofer and two for the miniwoofers.
The tweeter is powered by the circuit shown in fig. 15 and 16, using one TDA 2030A, with large feedback (Gv = 20dB) in order to minimize distortion. This device has also proved excellent performances as far as TIM is concerned (Ref. 1 and 2).
The diagrams of fig. 17 and 18 show the very low distortion characteristics of the proposed amplifiers. The loudspeakers used in the tests are RCF and Meriphon for the subwoofer, SIPE AS130 for the miniwoofers and SIPE DT25M for the «dome» tweeters. All the devices used as power amplifiers are assembled in the well known PENTAWATT package.

*Fig. 15 - 10W tweeter amplifier with split power supply*

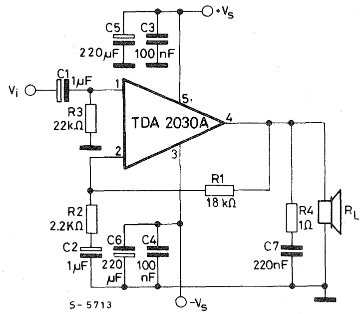



*Fig. 16 - P.C. board and component layout of the circuit of fig. 15 (1:1 scale)*

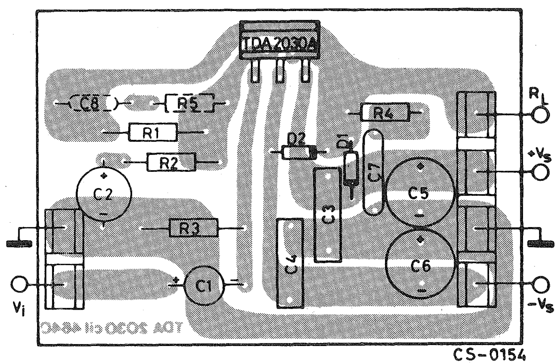



*Fig. 17 - Harmonic distortion vs. output power (subwoofer amplifiers)*

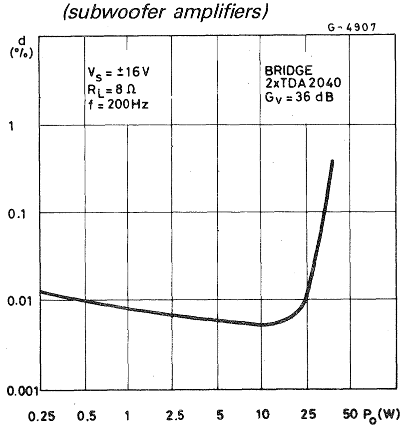
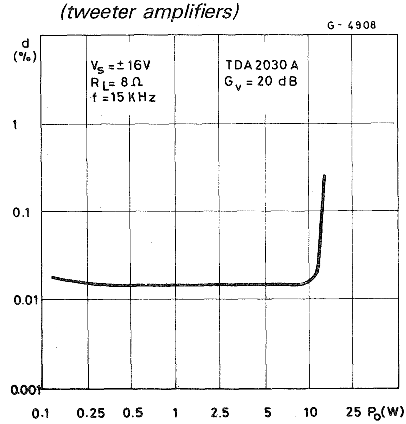



*Fig. 18 - Harmonic distortion vs. output power (tweeter amplifiers)*



## REFERENCES:

*(1) TIM distortion in monolithic ICs: measurements and simulation by P. Antoniazzi, P. Antognetti and E. Meda. 68 th AES convention, March 81.*

*(2) Measuring TIM in audio amplifiers by P. Antoniazzi, C. Buongiovanni and S. Tintori. Wireless world, May 1981.*

*(3) Dual-Slope filters optimize speaker's crossover response by P. Antoniazzi and A. Hennigan, Electronics, June 1980.*

*(4) Active crossover networks for non coincident drivers by S.H. Linkwitz, Journal of AES, Jan. Febr. 1976.*

*(5) Electronic crossover networks and their contribution to improved loudspeaker transient response by A.P. Smith, Journal of AES, Sept. 1971.*

*(6) The «LEDE» concept for the control of acoustic parameters by D. Davis and C. Davis, 63 rd AES Convention, May 1979.*

*(7) An acoustically small loudspeaker by R.I. Harcourt, Wireless world, Oct. Nov. 1980.*

*(8) Active Loudspeaker System using monolithic ICs by P. Antoniazzi and L. Crespi, 73 th AES Convention, March 83.*

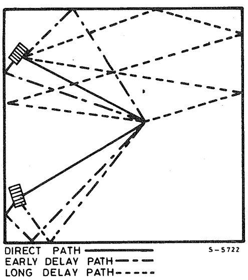

## APPENDIX I

**Early delay reflections**

As the HiFi equipments becomes less and less distorted, the performance of the acoustic environment has increased in significance to the point where many traditional concepts on listening rooms can be shown to be inadeguate.

The new concepts evolved from observations of the interaction of very early reflections with the direct sound emitted by a speaker box in a listening room. These observations where made by means of time-delay spectrometry (TDS).

*Fig. 19 - Reflections in a listening room*



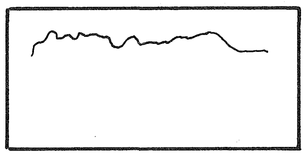

TDS is a unique and valuable measurement technique (developed by R. Heyser of California Inst. Research Found) which allows to study the reflection-by-reflection construction of what is popularly calleed «room modes».

The key observation, overlooked in the old literature, is that a reflection combining with the direct sound from a loudspeaker, both reflection and direct sound having nearly equal levels, causes «comb filters», and that the shorter the delay experienced by the reflection, the broader are the individual response anomalies which constitute the observed comb filter.

Fig. 19 and 20 shows a typical sound field development in a listening room and it can be seen that many path lengths must occur between loudspeaker and

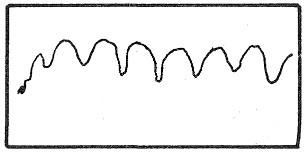
*Fig. 20 - «Comb filter» effect caused by room reflections.*

A)



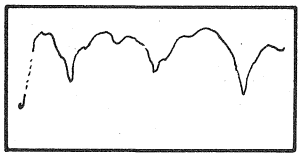
*Direct sound field response is from 10 Hz to 20 KHz*

B)



*Direct and reflected sound field of total distance between the direct and reflected sound field is 34 cm*

C)



*Total distance between the direct and the reflected sound field is 17 cm*

listener. These path lengths may be defined as follows:

A) direct path, effectively anechoic

B) early path lengths, arriving up to 10 ms later than the direct sound.

C) long path lenghts

D) reverberant sound field created by multiple path lenghts and defined in terms of the RT60 of the room

The reflections having the most distruptive effect are (B) which cause phase cancellation at frequencies defined as $F = \frac{500}{\Delta t}$ where $\Delta t$ is the path difference in ms.

Path lengths in eccess of 10ms can, of course, produce similar phase cancellation, but they have less distruptive effect for the following reasons.

Their amplitude is considerably lower as they approximate inverse square law decay.

They intensity may be reduced by two or more reflections from absorbent surfaces, and they are also subject to the «Haas effect» which is the ability of the ear to discriminate between direct sound and echoes.

Pratically with the new concepts for a good HiFi listining room, the specs are: a very hard surface, very diffuse live and for the entire room in front of the speaker boxes, while the rear wall was made as absortive as pratical, thus avoiding early delay reflections.

# APPENDIX II

## POWER AMPLIFIERS

### Output voltage and current versus output power

| $P_o$ (W) | $R_L = 4\Omega$ | | | | $R_L = 8\Omega$ | | | |
|---|---|---|---|---|---|---|---|---|
| | $V_o$ (V) | $V_{peak}$ (V) | $I_o$ (A) | $I_{peak}$ (A) | $V_o$ (V) | $V_{peak}$ (V) | $I_o$ (A) | $I_{peak}$ (A) |
| 1.0 | 2.00 | 2.83 | 0.50 | 0.71 | 2.83 | 4.00 | 0.35 | 0.50 |
| 1.5 | 2.45 | 3.46 | 0.61 | 0.87 | 3.46 | 4.90 | 0.43 | 0.61 |
| 2.0 | 2.83 | 4.00 | 0.71 | 1.00 | 4.00 | 5.66 | 0.50 | 0.71 |
| 2.5 | 3.16 | 4.47 | 0.79 | 1.12 | 4.47 | 6.32 | 0.56 | 0.79 |
| 3.0 | 3.46 | 4.90 | 0.87 | 1.22 | 4.90 | 6.93 | 0.61 | 0.87 |
| 3.5 | 3.74 | 5.29 | 0.94 | 1.32 | 5.29 | 7.48 | 0.66 | 0.94 |
| 4.0 | 4.00 | 5.66 | 1.00 | 1.41 | 5.66 | 8.00 | 0.71 | 1.00 |
| 4.5 | 4.24 | 6.00 | 1.06 | 1.50 | 6.00 | 8.49 | 0.75 | 1.06 |
| 5.0 | 4.47 | 6.32 | 1.12 | 1.58 | 6.32 | 8.94 | 0.79 | 1.12 |
| 5.5 | 4.69 | 6.63 | 1.17 | 1.66 | 6.63 | 9.38 | 0.83 | 1.17 |
| 6.0 | 4.90 | 6.93 | 1.22 | 1.73 | 6.93 | 9.80 | 0.87 | 1.22 |
| 7.0 | 5.29 | 7.48 | 1.32 | 1.87 | 7.48 | 10.58 | 0.94 | 1.32 |
| 8.0 | 5.66 | 8.00 | 1.41 | 2.00 | 8.00 | 11.31 | 1.00 | 1.41 |
| 9.0 | 6.00 | 8.49 | 1.50 | 2.12 | 8.49 | 12.00 | 1.06 | 1.50 |
| 10.0 | 6.32 | 8.94 | 1.58 | 2.24 | 8.94 | 12.65 | 1.12 | 1.58 |
| 12.0 | 6.93 | 9.80 | 1.73 | 2.45 | 9.80 | 13.86 | 1.22 | 1.73 |
| 15.0 | 7.75 | 10.95 | 1.94 | 2.74 | 10.95 | 15.49 | 1.37 | 1.94 |
| 20.0 | 8.94 | 12.65 | 2.24 | 3.16 | 12.65 | 17.89 | 1.58 | 2.24 |
| 25.0 | 10.00 | 14.14 | 2.50 | 3.54 | 14.14 | 20.00 | 1.77 | 2.50 |
| 30.0 | 10.95 | 15.49 | 2.74 | 3.87 | 15.49 | 21.91 | 1.94 | 2.74 |
| 35.0 | 11.83 | 16.73 | 2.96 | 4.18 | 16.73 | 23.66 | 2.09 | 2.96 |
| 40.0 | 12.65 | 17.89 | 3.16 | 4.47 | 17.89 | 25.30 | 2.24 | 3.16 |
| 45.0 | 13.42 | 18.97 | 3.35 | 4.74 | 18.97 | 26.83 | 2.37 | 3.35 |
| 50.0 | 14.14 | 20.00 | 3.54 | 5.00 | 20.00 | 28.28 | 2.50 | 3.54 |
| 60.0 | 15.49 | 21.91 | 3.87 | 5.48 | 21.91 | 30.98 | 2.74 | 3.87 |
| 70.0 | 16.73 | 23.66 | 4.18 | 5.92 | 23.66 | 33.47 | 2.96 | 4.18 |
| 80.0 | 17.89 | 25.30 | 4.47 | 6.32 | 25.30 | 35.78 | 3.16 | 4.47 |
| 90.0 | 18.97 | 26.83 | 4.74 | 6.71 | 26.83 | 37.95 | 3.35 | 4.74 |
| 100.0 | 20.00 | 28.28 | 5.00 | 7.07 | 28.28 | 40.00 | 3.54 | 5.00 |
| 120.0 | 21.91 | 30.98 | 5.48 | 7.75 | 30.98 | 43.82 | 3.87 | 5.48 |
| 150.0 | 24.49 | 34.64 | 6.12 | 8.66 | 34.64 | 48.99 | 4.33 | 6.12 |
| 200.0 | 28.28 | 40.00 | 7.07 | 10.00 | 40.00 | 56.57 | 5.00 | 7.07 |

## dB and Power Ratio

| dB | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.000 | 1.023 | 1.047 | 1.072 | 1.096 | 1.122 | 1.148 | 1.175 | 1.202 | 1.230 |
| 1 | 1.259 | 1.288 | 1.318 | 1.349 | 1.380 | 1.413 | 1.445 | 1.479 | 1.514 | 1.549 |
| 2 | 1.585 | 1.622 | 1.660 | 1.698 | 1.738 | 1.778 | 1.820 | 1.862 | 1.905 | 1.950 |
| 3 | 1.995 | 2.042 | 2.089 | 2.138 | 2.188 | 2.239 | 2.291 | 2.344 | 2.399 | 2.455 |
| 4 | 2.512 | 2.570 | 2.630 | 2.692 | 2.754 | 2.818 | 2.884 | 2.951 | 3.020 | 3.090 |
| 5 | 3.162 | 3.236 | 3.311 | 3.388 | 3.467 | 3.548 | 3.631 | 3.715 | 3.802 | 3.890 |
| 6 | 3.981 | 4.074 | 4.169 | 4.266 | 4.365 | 4.467 | 4.571 | 4.677 | 4.786 | 4.898 |
| 7 | 5.012 | 5.129 | 5.248 | 5.370 | 5.495 | 5.623 | 5.754 | 5.888 | 6.026 | 6.166 |
| 8 | 6.310 | 6.457 | 6.607 | 6.761 | 6.918 | 7.079 | 7.244 | 7.413 | 7.586 | 7.762 |
| 9 | 7.943 | 8.128 | 8.318 | 8.511 | 8.710 | 8.913 | 9.120 | 9.333 | 9.550 | 9.772 |
| 10 | 10.00 | 10.23 | 10.47 | 10.72 | 10.96 | 11.22 | 11.48 | 11.75 | 12.02 | 12.30 |
| 11 | 12.59 | 12.88 | 13.18 | 13.49 | 13.80 | 14.13 | 14.45 | 14.79 | 15.14 | 15.49 |
| 12 | 15.85 | 16.22 | 16.60 | 16.98 | 17.38 | 17.78 | 18.20 | 18.62 | 19.05 | 19.50 |
| 13 | 19.95 | 20.42 | 20.89 | 21.38 | 21.88 | 22.39 | 22.91 | 23.44 | 23.99 | 24.55 |
| 14 | 25.12 | 25.70 | 26.30 | 26.92 | 28.18 | 28.18 | 28.84 | 29.51 | 30.20 | 30.90 |
| 15 | 31.62 | 32.36 | 33.11 | 33.88 | 34.67 | 35.48 | 36.31 | 37.16 | 38.06 | 38.90 |
| 16 | 39.81 | 40.74 | 41.69 | 42.66 | 43.65 | 44.67 | 45.71 | 46.77 | 47.86 | 49.98 |
| 17 | 50.12 | 51.29 | 52.48 | 53.70 | 54.95 | 56.23 | 57.54 | 58.88 | 60.26 | 61.66 |
| 18 | 63.10 | 64.57 | 66.07 | 67.61 | 69.18 | 70.79 | 72.44 | 74.13 | 75.86 | 77.62 |
| 19 | 79.43 | 81.28 | 83.18 | 85.11 | 87.10 | 89.13 | 91.20 | 93.33 | 95.50 | 97.72 |
| 20 | 100.00 | 102.3 | 104.7 | 107.2 | 109.6 | 112.2 | 114.8 | 117.5 | 120.2 | 123.0 |

## dB and Voltage Ratio

| dB | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.000 | 1.012 | 1.023 | 1.035 | 1.047 | 1.059 | 1.072 | 1.084 | 1.097 | 1.109 |
| 1 | 1.122 | 1.135 | 1.148 | 1.161 | 1.175 | 1.188 | 1.202 | 1.216 | 1.230 | 1.244 |
| 2 | 1.259 | 1.274 | 1.288 | 1.303 | 1.318 | 1.333 | 1.349 | 1.365 | 1.380 | 1.396 |
| 3 | 1.413 | 1.430 | 1.445 | 1.462 | 1.479 | 1.496 | 1.515 | 1.532 | 1.550 | 1.567 |
| 4 | 1.585 | 1.604 | 1.621 | 1.640 | 1.659 | 1.679 | 1.699 | 1.718 | 1.739 | 1.758 |
| 5 | 1.778 | 1.799 | 1.819 | 1.840 | 1.862 | 1.884 | 1.906 | 1.927 | 1.950 | 1.972 |
| 6 | 1.995 | 2.019 | 2.041 | 2.065 | 2.089 | 2.113 | 2.139 | 2.163 | 2.189 | 1.212 |
| 7 | 2.239 | 2.266 | 2.290 | 2.317 | 2.344 | 2.371 | 2.400 | 2.427 | 2.456 | 2.483 |
| 8 | 2.512 | 2.542 | 2.570 | 2.600 | 2.630 | 2.660 | 2.693 | 2.723 | 2.756 | 2.786 |
| 9 | 2.818 | 2.852 | 2.883 | 2.917 | 2.950 | 2.984 | 3.021 | 3.055 | 3.091 | 3.125 |
| 10 | 3.162 | 3.200 | 3.235 | 3.273 | 3.311 | 3.349 | 3.390 | 3.428 | 3.469 | 3.507 |
| 11 | 3.548 | 3.591 | 3.630 | 3.672 | 3.715 | 3.757 | 3.803 | 3.846 | 3.892 | 3.935 |
| 12 | 3.981 | 4.029 | 4.073 | 4.120 | 4.168 | 4.216 | 4.268 | 4.315 | 4.367 | 4.415 |
| 13 | 4.467 | 4.521 | 4.570 | 4.623 | 4.678 | 4.731 | 4.789 | 4.842 | 4.900 | 4.954 |
| 14 | 5.012 | 5.072 | 5.127 | 5.187 | 5.248 | 5.308 | 5.373 | 5.435 | 5.498 | 5.558 |
| 15 | 5.623 | 5.690 | 5.752 | 5.820 | 5.887 | 5.955 | 6.028 | 6.095 | 6.168 | 6.236 |
| 16 | 6.310 | 6.386 | 6.455 | 6.531 | 6.607 | 6.682 | 6.764 | 6.840 | 6.922 | 6.998 |
| 17 | 7.080 | 7.165 | 7.243 | 7.328 | 7.413 | 7.498 | 7.590 | 7.675 | 7.767 | 7.852 |
| 18 | 7.943 | 8.038 | 8.126 | 8.221 | 8.316 | 8.412 | 8.515 | 8.610 | 8.713 | 8.809 |
| 19 | 8.913 | 9.020 | 9.118 | 9.225 | 9.332 | 9.439 | 9.555 | 9.662 | 9.778 | 9.885 |
| 20 | 10.00 | 10.12 | 10.23 | 10.35 | 10.47 | 10.59 | 10.72 | 10.84 | 10.97 | 11.09 |

*Fig. 21 - Slew-rate vs. peak output voltage (optimum design area for Hi-Fi)*

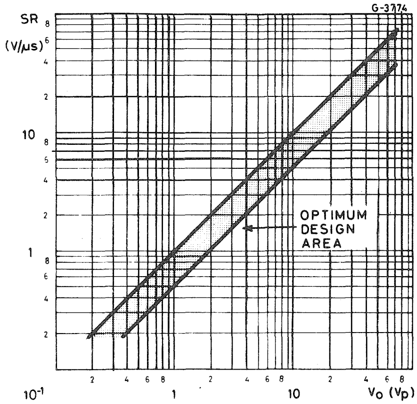



*Fig. 22 - Slew-rate and power bandwidth vs. peak output voltage (with optimum design area for Hi-Fi)*

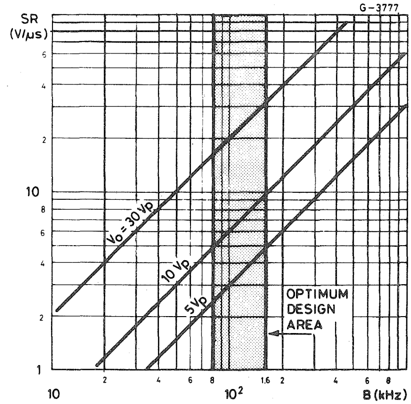



*Fig. 23 - Slew-rate and power bandwidth vs. output power for $R_L = 8\Omega$ (with optimum design area for Hi-Fi)*

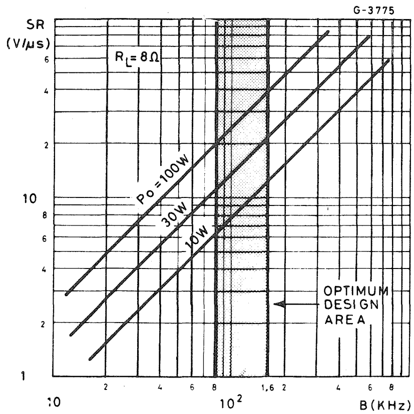
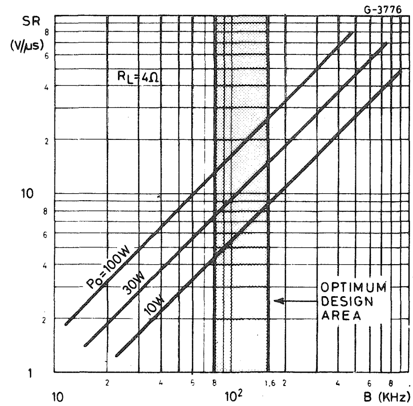



*Fig. 24 - Slew-rate and power bandwidth vs. output power for $R_L = 4\Omega$ (with optimum desing area for Hi-Fi)*



## NOISE

*Fig. 25 - Total input noise voltage vs. noise figure and bandwidth ($R_g = 600\Omega$)*

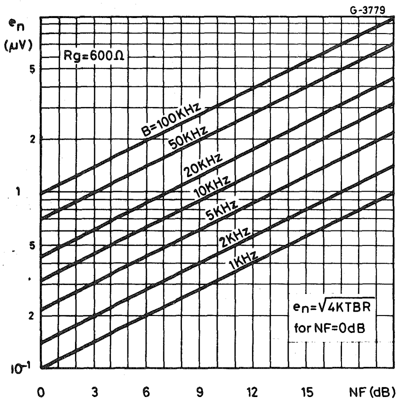



*Fig. 26 - Total input noise voltage vs. noise figure and bandwidth ($R_g = 10K\Omega$)*

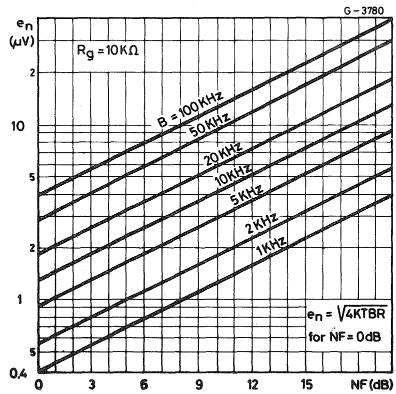



*Fig. 27 - Thermal noise voltage of a resistance vs. bandwidth*

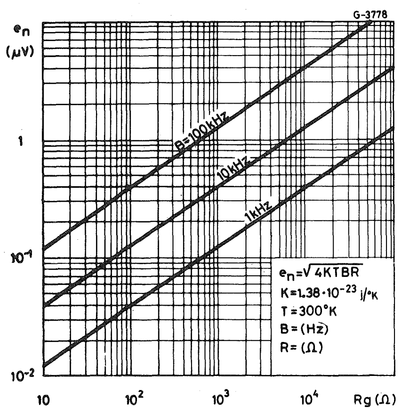
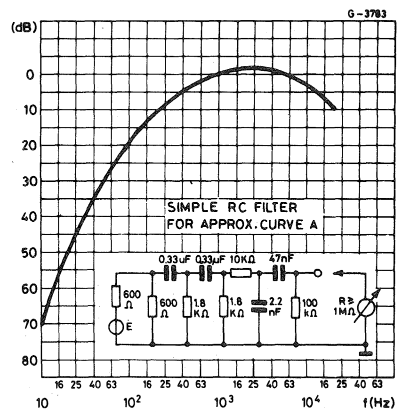



*Fig. 28 - Psophometric weighting (curve A)*



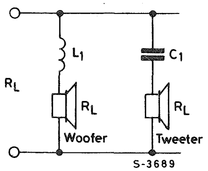
## FILTERS

### Cutoff frequency of 6 dB/octave RC filters (kHz)

| R (kΩ) | c (nF) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.2 | 1.5 | 1.8 | 2.2 | 2.7 | 3.3 | 3.9 | 4.7 | 5.6 | 6.8 | 8.2 | 10 |
| 1 | 159.1 | 132.6 | 106.1 | 88.42 | 72.34 | 58.95 | 48.23 | 40.81 | 33.86 | 28.42 | 23.41 | 19.41 | 15.92 |
| 1.2 | 132.6 | 110.5 | 88.42 | 73.68 | 60.29 | 49.12 | 40.19 | 34.01 | 28.22 | 23.68 | 19.50 | 16.17 | 13.26 |
| 1.5 | 106.1 | 88.42 | 70.74 | 58.95 | 48.23 | 39.30 | 32.15 | 27.21 | 22.58 | 18.95 | 15.60 | 12.94 | 10.61 |
| 1.8 | 88.42 | 73.68 | 58.95 | 49.12 | 40.19 | 32.75 | 26.79 | 22.67 | 18.81 | 15.79 | 13.00 | 10.78 | 8.84 |
| 2.2 | 72.34 | 60.29 | 48.23 | 40.19 | 32.88 | 26.79 | 21.92 | 18.55 | 15.39 | 12.92 | 10.64 | 8.82 | 7.23 |
| 2.7 | 58.95 | 49.12 | 39.30 | 32.75 | 26.79 | 21.83 | 17.86 | 15.11 | 12.54 | 10.53 | 8.67 | 7.19 | 5.89 |
| 3.3 | 48.23 | 40.19 | 32.15 | 26.79 | 21.92 | 17.86 | 14.61 | 12.37 | 10.26 | 8.61 | 7.09 | 5.88 | 4.82 |
| 3.9 | 40.81 | 34.01 | 27.21 | 22.67 | 18.55 | 15.11 | 12.37 | 10.46 | 8.68 | 7.29 | 6.00 | 4.98 | 4.08 |
| 4.7 | 33.86 | 28.22 | 22.58 | 18.81 | 15.39 | 12.54 | 10.26 | 8.68 | 7.20 | 6.05 | 4.98 | 4.13 | 3.39 |
| 5.6 | 28.42 | 23.68 | 18.95 | 15.79 | 12.92 | 10.53 | 8.61 | 7.29 | 6.05 | 5.08 | 4.18 | 3.47 | 2.84 |
| 6.8 | 23.41 | 19.50 | 15.60 | 13.00 | 10.64 | 8.67 | 7.09 | 6.00 | 4.98 | 4.18 | 3.44 | 2.85 | 2.34 |
| 8.2 | 19.41 | 16.17 | 12.94 | 10.78 | 8.82 | 7.19 | 5.88 | 4.98 | 4.13 | 3.47 | 2.85 | 2.37 | 1.94 |
| 10 | 15.92 | 13.26 | 10.61 | 8.84 | 7.23 | 5.89 | 4.82 | 4.08 | 3.39 | 2.84 | 2.34 | 1.94 | 1.59 |
| 12 | 13.26 | 11.05 | 8.84 | 7.37 | 6.03 | 4.91 | 4.02 | 3.40 | 2.82 | 2.37 | 1.95 | 1.62 | 1.33 |
| 15 | 10.61 | 8.84 | 7.07 | 5.89 | 4.82 | 3.93 | 3.21 | 2.72 | 2.26 | 1.89 | 1.56 | 1.29 | 1.06 |
| 18 | 8.84 | 7.37 | 5.89 | 4.91 | 4.02 | 3.27 | 2.68 | 2.27 | 1.88 | 1.58 | 1.30 | 1.08 | 0.88 |
| 22 | 7.37 | 6.03 | 4.82 | 4.02 | 3.29 | 2.68 | 2.19 | 1.85 | 1.54 | 1.29 | 1.06 | 0.88 | 0.72 |
| 27 | 5.89 | 4.91 | 3.93 | 3.27 | 2.68 | 2.18 | 1.79 | 1.51 | 1.25 | 1.05 | 0.87 | 0.72 | 0.59 |
| 33 | 4.82 | 4.02 | 3.21 | 2.68 | 2.19 | 1.79 | 1.46 | 1.24 | 1.03 | 0.86 | 0.71 | 0.59 | 0.48 |
| 39 | 4.08 | 3.40 | 2.72 | 2.27 | 1.85 | 1.51 | 1.24 | 1.05 | 0.87 | 0.73 | 0.60 | 0.50 | 0.41 |
| 47 | 3.39 | 2.82 | 2.26 | 1.88 | 1.54 | 1.25 | 1.03 | 0.87 | 0.72 | 0.60 | 0.50 | 0.41 | 0.34 |
| 56 | 2.84 | 2.37 | 1.89 | 1.58 | 1.29 | 1.05 | 0.86 | 0.73 | 0.60 | 0.51 | 0.42 | 0.35 | 0.28 |
| 68 | 2.34 | 1.95 | 1.56 | 1.30 | 1.06 | 0.87 | 0.71 | 0.60 | 0.50 | 0.42 | 0.34 | 0.28 | 0.23 |
| 82 | 1.94 | 1.62 | 1.29 | 1.08 | 0.88 | 0.72 | 0.59 | 0.50 | 0.41 | 0.35 | 0.28 | 0.24 | 0.19 |
| 100 | 1.59 | 1.33 | 1.06 | 0.88 | 0.72 | 0.59 | 0.48 | 0.41 | 0.34 | 0.28 | 0.23 | 0.19 | 0.16 |

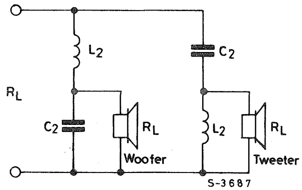
## LOUDSPEAKERS CROSSOVER FILTERS

*Fig. 29 - Two way (6 dB/octave)*



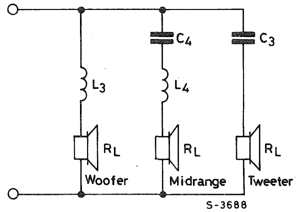

$$L_1 = \frac{R_L}{2\pi f_c} \qquad C_1 = \frac{1}{2\pi f_c R_L}$$

*Fig. 30 - Two way (12 dB/octave)*




$$L_2 = \frac{R_L\sqrt{2}}{2\pi f_c} \qquad C_2 = \frac{1}{2\pi f_c R_L\sqrt{2}}$$

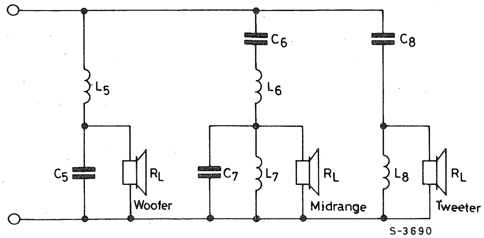
*Fig. 31 - Three way (6 dB/octave)*




$$L_3 = \frac{R_L}{2\pi f_1} \qquad C_3 = \frac{1}{2\pi f_2 R_L}$$

$$L_4 \cong \frac{R_L}{2\pi f_2} \qquad C_4 \cong \frac{1}{2\pi f_1 R_L}$$

*Fig. 32 - Three way (12 dB/octave)*




$$L_5 = \frac{R_L\sqrt{2}}{2\pi f_1} \qquad C_5 = \frac{1}{2\pi f_1 R_L\sqrt{2}}$$

$$L_6 \cong \frac{R_L\sqrt{2}}{2\pi f_2} \qquad C_6 \cong \frac{1}{2\pi f_1 R_L\sqrt{2}}$$

$$L_7 \cong \frac{R_L\sqrt{2}}{2\pi f_1} \qquad C_7 \cong \frac{1}{2\pi f_2 R_L\sqrt{2}}$$

$$L_8 = \frac{R_L\sqrt{2}}{2\pi f_2} \qquad C_8 = \frac{1}{2\pi f_2 R_L\sqrt{2}}$$

**Note:** When the two complementary filters (HP and LP) are correctly terminated, the impedance presented at their common input will be a constant resistance equal to $R_L$ over the passband.

*Fig. 33 - Frequency response of two way crossover filters (6 dB/octave)*

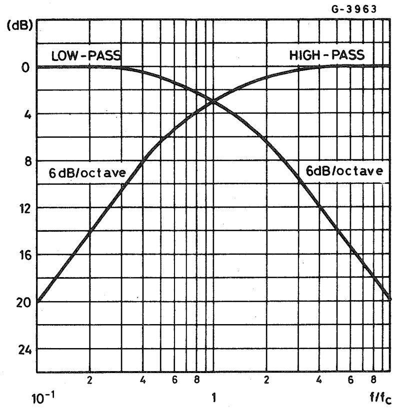



*Fig. 34 - Frequency response of two way crossover filters (12 dB/octave)*

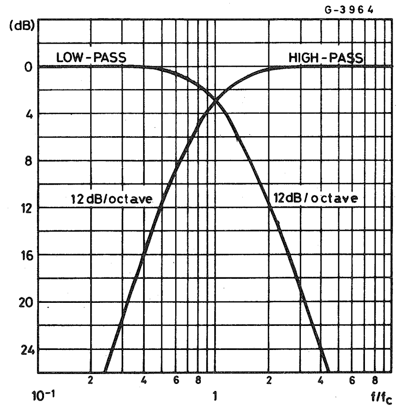



*Fig. 35 - Phase response of two way crossover filters (6 dB/octave)*

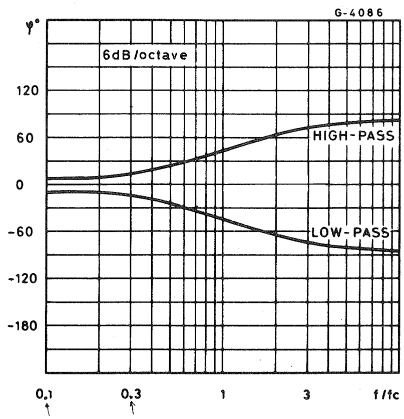



*Fig. 36 - Phase response of two way crossover filters (12 dB/octave)*

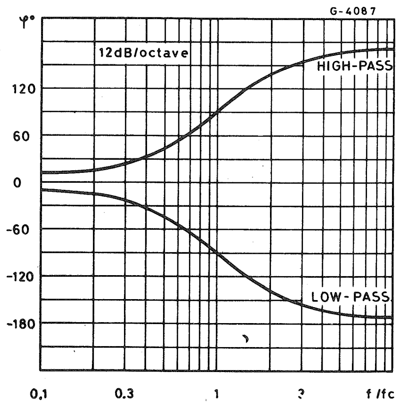


*Fig. 37 - Constant resistance two way crossover filters for $R_L = 8\Omega$ (6 dB/ octave)*

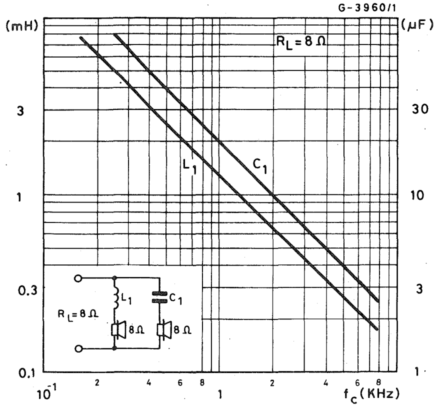



*Fig. 38 - Constant resistance two way crossover filters for $R_L = 4\Omega$ (6 dB/ octave)*

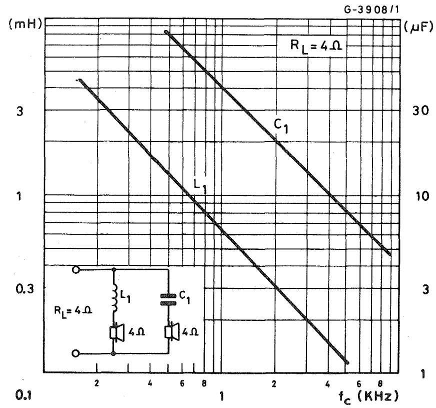



*Fig. 39 - Constant resistance two way crossover filters for $R_L = 8\Omega$ (12 dB/ octave)*

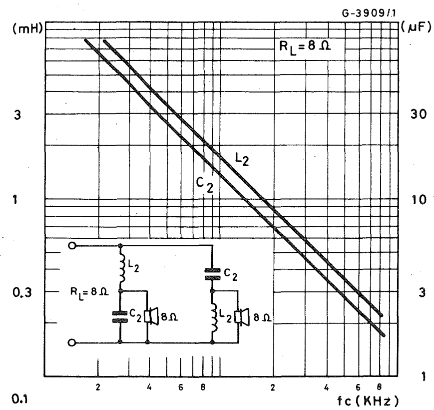
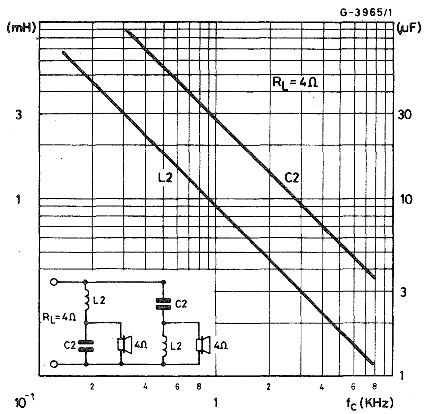



*Fig. 40 - Constant resistance two way crossover filters for $R_L = 4\Omega$ (12 dB/ octave)*



## SOUND

### Typical sound pressures

| Sound level dB | Intensity W/m² | Environment conditions |
|---|---|---|
| 150 | 1000 | Close to jet aircraft |
| 140 | 100 | Threshold of pain |
| 130 | 10 | Pneumatic drill |
| 120 | 1 | Loud auto horn (at 1m) |
| 110 | — | Subway, train passing |
| 100 | $10^{-2}$ | Noisiest spot at Niagara falls (92 dB) |
| 90 | — | Inside motor bus |
| 80 | $10^{-4}$ | Average traffic (Big city) |
| 70 | — | High volume TV |
| 60 | $10^{-6}$ | Conversational speech |
| 50 | — | Living room |
| 40 | $10^{-8}$ | Library |
| 30 | — | Speech (low level) |
| 20 | $10^{-10}$ | Broadcasting studio |
| 10 | — | Threshold of hearing |
| 0 | $10^{-12}$ | |

**Note:** 0 dB is equal to 0.0002 $\mu$ bar, which is the weakest sound pressure to be detected by an «average» person at 1000 Hz and corresponds, by international agreement, to 20 $\mu$ pascal (20 $\mu$ Pa).

*Fig. 41 - Equal loudness curves*

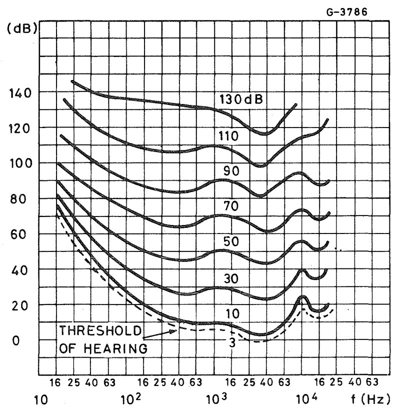
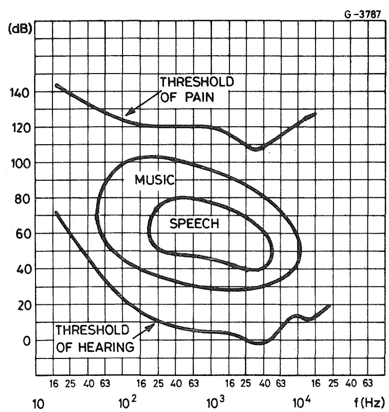



*Fig. 42 - Hearing area for speech and music*



## Loudspeakers efficiency

If we assume spherical free space with an omnidirectional source radiating freely outwards from the centre, source power emission can thus be calculated from:

$$P_o = 4\,\pi W_M d^2$$

where $P_o$ is the source emission in acoustical watts, $W_M$ the mean power in $W/m^2$ and d the distance from the source in metres.
Under true free-field conditions and assuming an omnidirectional source an intensity of 96 dB at 1 mentre requires an acoustical emission of 50 mW.
Pratically, the efficiency measurement (as Din. 45500) are made under hemispherical free space conditions (anechoic chamber, with radiation in the form of half a sphere in front of the loudspeaker box and no emission from the rear).
In these conditions, an intensity of 96 dB at 1 metre is obtained with 25 mW acoustical power.
With and electrical input power of 1W, 89 dB means 0.5% efficiency and 86 dB -0.25% efficiency.

*Fig. 43 - Electrical power ($P_o$) and loudspeaker efficiency (dB) required for a given room volume ($m^3$)*

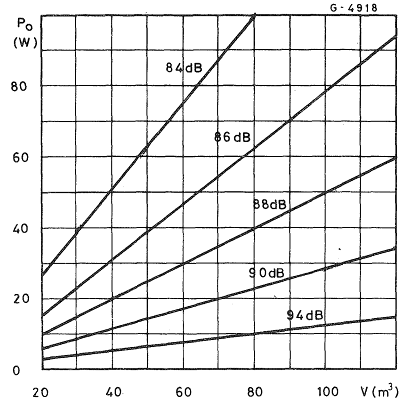



*Fig. 44 - Dynamic range of disc music (sound pressure referred to threshold of audibility or 20 μ Pa)*

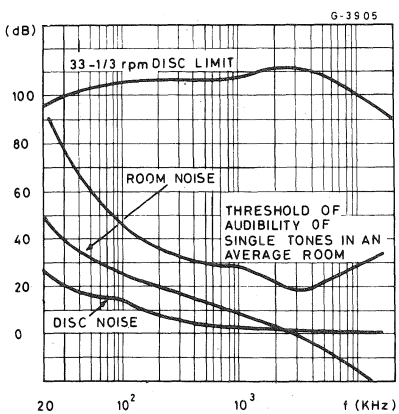
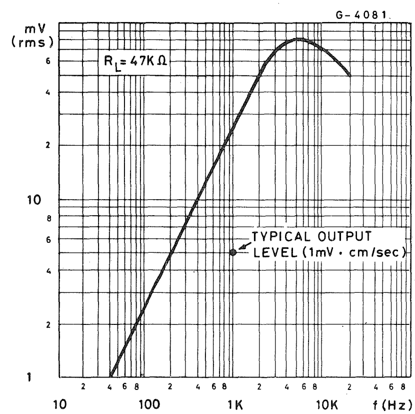



*Fig. 45 - Maximum output level of High Quality magnetic cartridge vs. frequency*

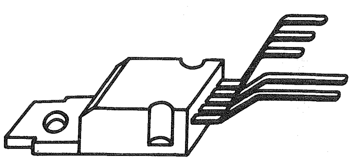


## SGS RANGE OF AUDIO POWER AMPLIFIERS (test conditions; d=10%, f=1 KHz)

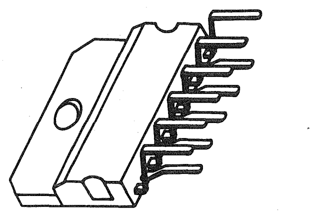
| Supply (V) | Device | Output Power (W) | | | Note |
|---|---|---|---|---|---|
| | | $R_L=2\Omega$ | $R_L=4\Omega$ | $R_L=8\Omega$ | |
| 3 | TDA 2820M | | 2×0.11 | | 0.35W Bridge 4Ω |
| 4.5 | TBA 820M | | 0.32 | | |
| | TDA 2820M | | 2×0.32 | | 1W Bridge 4Ω |
| 6 | TBA 820M | | 0.75 | 0.45 | |
| | TDA 1904 | | 0.8 | | |
| | TDA 2820M | | 2×0.65 | | 1.35W Bridge 8Ω |
| 9 | TBA 820M | | 1.6 | 1.2 | |
| | TDA 1904 | | 2.2 | | |
| | TDA 1905 | | 2.5 | 1.3 | |
| 14 | TDA 1904 | | 4.5 | | |
| | TDA 1905 | | 5.4 | 3 | |
| | TDA 1908 | | 5.8 | 3 | |
| | TDA 2002 | 8 | 5.2 | | |
| | TDA 2003 | 10 | 6 | | 12 |
| | TDA 2004 | 2×10 | 2×6.5 | | 2×11 |
| | TDA 2005 | 2×10 | 2×6.5 (°) | | 2×11 } $R_L=1.6\Omega$ |
| 18 | TCA 940N | | 9 | 5 | |
| | TDA 1905 | | | 5.5 | |
| | TDA 1908 | | 9 | 5 | |
| 22 | TDA 2008 | | 12 | 8 | |
| 23 | TDA 2009 | | 2×10 | (°) | |
| 24 | TDA 1905 | | | | 5.3 |
| | TDA 1908 | | | | 5 } $R_L=16\Omega$ |
| | TDA 2006 | | 12 | 8 | |
| 28 | TDA 2010 * | | 12 | 9 | |
| | TDA 2030 * | | 14 | 9 | |
| 32 | TDA 2030A * | | 18 | 12 | |
| | TDA 2040 * | | 22 | 12 | |

(°) 20W in Bridge — (*) d=0.5%, f = 1KHz

*PENTAWATT PACKAGE*



*MULTIWATT 11 PACKAGE*





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