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He grew up in an artist's family - the grandfather being a famous tenor, the father a piano player, started music and piano lessons at 4 and had the fortune of experiencing regular home concerts. With 5 years - after a special permission was secured - he was able to join his parents in attending a wide variety of concerts in the Tonhalle Zuerich. A career as musician was predicted by teachers and musicians. Realizing that in the life of a professional musician there is a certain danger of monotony he took a firm decision to keep the love for music alive, but not as a professional musician. Even before the teenage years his interests were widespread and football was left aside for the study of more fascinating subjects, one of them being the acoustics of concert halls. With 14 he built his first transistorized power amplifier based on the usual 'textbook knowledge'. The

POWER AMPLIFIERS AND REAL-WORLD SPEAKER IMPEDANCES

DRIVE REQUIREMENTS AND AMPLIFIER SELECTION CRITERIA

The drive requirements that today's speaker demand are much underrated.....

The selection of a power amplifier for a certain application depends on many variables, such as the true load impedance, room size and room acoustics, requested SPL (sound pressure level), etc. One of the most important characteristics that determines the quality of the entire system is the interface between amplifier and speaker. While a certain amplifier may work fine with a certain type of speakers, it might not interface well with other seemingly similar speaker. This is often due to the impedance and phase characteristics of the speaker and the variation of this characteristics when the speaker is driven by dynamic (music) signals. There is no doubt that the established criteria of measuring impedance (standard measurements are done with static signals and low levels - typically 1 Watt only) need to be re-evaluated. They are not realistic.

The drive requirements that today's speakers demand from amplifiers are much underrated. In addition to the static resistance - which itself varies greatly over the frequency range (a typical speaker with a nominal 8 Ohm impedance rating can easily vary from 50 Ohms to below 2 Ohms) - there are often huge phase changes that approach a cosine phi of 1 (the worst case where the maximum current is required at exactly the same time when the amplifier is delivering its maximum voltage swing). The phase is also changing with frequency, not exactly simplifying matters. In terms of a roughly comparable resistive rating, this would correspond to a load resistance of between 1 and 50 Ohms for a typical 8 Ohm speaker. Some critical speakers are even more demanding! Despite contrary claims by manufacturers there are really very few amplifiers that have been designed to stable drive such loads and fulfil the above requirements. Most amplifiers' protection circuits - be they fuses voltage and/or current limiting, input stage, driver stage and other forms of compression or limiting - will activate with such loads and cause compression, signal clamping, dynamic limiting and/or distortion. Power supplies collapse under such stress conditions, while the predriver and driver stages easily run out of reserve and provoke all kinds of momentary strange reactions. This creates various types of dynamic distortions that cannot be measured but can be audible and detract from the accuracy of the reproduction.

As if the above was not difficult enough, there is a third phenomenon that aggravates the situation. After excitation the voice-coil/diaphragm assembly tries to return to the normal central position. When the voice coil moves back to this position, the magnetic field in the gap induces a current called "Back-EMF" (electro-motive force) in the voice-coil. This is a current feedback into the amplifier's output stage and which can - if the amplifier has overall feedback - even reflect back right to the input stage. Under certain circumstances this result in the input stage being negatively influenced by the Back-EMF; it will actually correct for a signal that is not an error signal but said Back-EMF. In addition the already strained output stage is now required to dissipate the back-EMF impulse current. The larger the diaphragm excursion the higher the Back-

EMF current. This is obviously more critical at low frequencies where diaphragm movement is large and results in a compressed and ill-defined bass reproduction. Depending on the speaker's construction the low-mid and mid-frequencies will be negatively influenced as well. In practice, with certain amplifiers one can measure and sometimes actually see that the diaphragm travel of the bass driver increases linearly only up to a certain power level, at which the amplifier looses control and the drivers are no longer properly damped. Above that level the sound simply disintegrates. With many amplifiers this is happening much below the rated power output of the amplifier which explains why amplifiers with similar power output ratings can have such large differences in output and sound.

Using special dynamic control techniques in FM Acoustics amplifiers, the diaphragm is properly driven and damped. Diaphragm travel simply increases to the limit of the driver's linear excursion. Obviously, this way the diaphragm is driven more accurate. This results in a much improved reproduction provided the amplifier has none of the above-mentioned compression or limiting. Unfortunately though, almost all amplifiers suffer from some limiting and compression circuitry or from the negative effects of fuses.

Here we also see why it is of utmost importance to keep the source impedance that the speaker sees as low as possible (the speaker cable and connector resistance must be taken into account but this is not done with existing measurement techniques! It is the entire system and not just individual units that define performance). Because this interface is so important true quality speaker cables bring definite improvements.

Cables, Damping and Interference Rejection

In amplifier-speaker interfacing a variety of criteria have to be observed, and the ideal cable has an optimal mix of these criteria. The criteria that has the most significant influence on the transmission quality of cable - the transfer characteristics - is often neglected for some other - often visual - aspect. Hand in hand with better signal transmission goes less interference. With less interference entering the cable there is obviously also less negative influence on the amplifier/speaker interface.

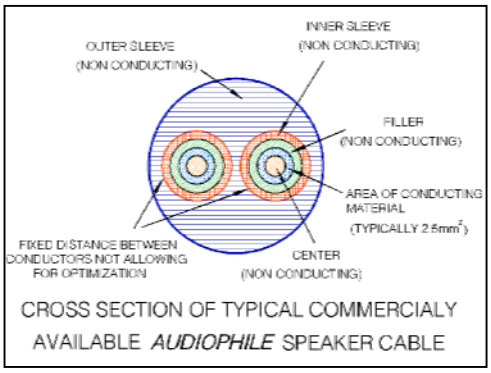
massive improvement in the control of the voice-coil/diaphragm movements.

The amplifier controls the speaker via damping. This increases in direct proportion to improved conduction of the cable. Such lowest-loss signal transfer results in massive improvement in the control of the voice-coil/diaphragm movements and overall system performance. Real-world speaker impedances demand huge output currents from the amplifier.

The pristine signal from the amplifier must be transferred to the low-impedance speaker load with minimal resistance to signal transfer and with lowest losses. Many of the cables used to connect amplifiers to speakers boast a formidable outside diameter, but the majority of such cables contain inordinate amounts of cheap insulating materials, fibers and other non-conductive material (see Fig. 1). Using such fillers the cable's visual appearance becomes more massive, which may make an impression on some uninformed buyers. Obviously, such non-conducting materials do not in the least degree help signal transfer. Of course it is magnitudes cheaper to use such fillers rather than using high-performance copper. However, electrons do not really like

amplifier had good technical data but was totally amusical. This divergence rose his suspicion. With help from a sympathetic librarian he was given a special pass for the library of the ETH Zuerich (the MIT of Europe) where he spent every minute of his spare time studying. Realizing how limited the actual knowledge was and how far away from accurate reproduction the existing designs were he started to construct his own. The rumours about the quality of his designs soon resulted in requests from musicians. Products were built to order in his spare time while he was still studying. His wide practical experience and his in-depth knowledge of subjects as diverse as music, electronics, mechanical design, acoustics, vibration technology etc. resulted in major developments, some of which were patented. His natural scepticism towards the usual dogmas have always allowed him insights that went beyond current knowledge. Many of his original ideas have been copied by other designers the world over. In May 1973, aged 21, he founded FM ACCOUSTICS LTD. and has since continuously pursued his goal of absolute accuracy with his dedicated team. FM ACCOUSTICS'

quest for the ultimate in musicality and precision has become legendary.



CROSS SECTION OF TYPICAL COMMERCIALY AVAILABLE *AUDIOPHILE* SPEAKER CABLE

plastics, fibers or robber or other non-conductive materials, so all the impressive looking cables that are mainly made up filler materials are really quite useless. In such cables the actual conducting material itself is often quite a minor part of these materials used. It is, therefore, a good idea to check the weight of a speaker cable, as it gives a general indication of the amount of actual conducting material that is used (materials that conduct well are also relatively heavy.)

It is a fact that for really accurate signal transfer the actual conducting area of all currently available cables is much too small. Because of this limitation of existing cables, the massive clean damping that is provided by well-designed amplifiers is lowered dramatically at the speaker end - with a corresponding drop in reproduction accuracy. Much better conduction than is generally acknowledged is required, for a higher damping at the speaker is synonymous with more precise control of the diaphragm/voice-coil. In reasonable quality installations a purified copper square section of at least 10mm2 (AWG7) is the absolute minimum. With demanding speaker loads AWG5 (I6.5mm2) or even better, AWG3 (25.6mm2) is required. As no wide-band width cable of this calibre is available as standard, engineers at FM ACOUSTICS in co-operation with the world's leading experts on cable technology have designed a unique cable that features a variety of proprietary characteristics. FOORCELINES guarantee optimal signal transfer, truly highest damping and perfect control of the speakers.

Usually damping factors are measured with a static sine wave signal of 1W at the amplifier's output connectors. This is nonsense. In actual use speakers require much higher levels than 1W from the amplifier and are supplied with very complex and dynamic music signals. More realistic measurement standards must be developed, as values obtained with currently used measurement techniques are next to useless. It is damping at the speakers (and not at the amplifier's output) that defines performance and this is why true no-compromise precision transfer cables result in such dramatic improvements.

Connectors

The widely used standard 4mm banana plugs and five way binding posts are by no means sufficient when highest accuracy power transfer is required. In fact, the connectors currently used by amplifier manufacturers do not provide satisfactory signal transfer, especially when driving critical speaker loads with very dynamic music material. Most connectors have too high contact resistance, do not make a vibration-proof secure contact and have marginal current handling capability. Connectors for high currents handling and extreme dynamic ranges must be able to accommodate the larger square sections of massive cables and provide an ultra-low resistance contact to guarantee perfect signal transfer to driver. Picture 2 shows the special 200A connectors used exclusively in FM ACOUSTICS

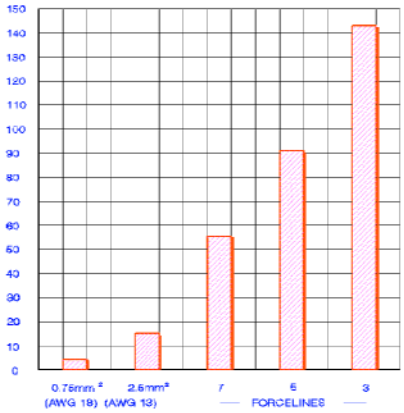


Fig. 2
Effective Damping Factor at speakers using a 5m. run of cable and assuming an amplifier damping factor of 1000.

Resolution Series. (See Fig. 2)

Resolution Series power amplifier and preamplifier, flagship of FM Acoustics

Gold

It is a popular belief that gold provides the ultimate conduction and is the best contact material. This probably comes from the emotional value with which gold is regarded. While gold is a good contact material for very low voltages and currents and has its value in certain applications where aggressive substances are active, it is not ideal where high currents and voltages must be conducted. Other material mixtures are better suited as contact materials for levels above about 0.5-1V. It is therefore nonsense to gold-plate connectors. This applies to speaker connectors, spade lugs or other cable terminations that carry higher levels.

Physical Conductor Layout

An optimal solution is achieved when cables having two seperate conductors are used. This way the physical layout of the cables (which of course influences the performance of the system) can be optimised for each amplifier-speaker combination. By laying the cables either a few cm apart, close together or twisting them together the best performance can be found empirically. Most audiophile speaker cables do not allow this optimisation because both conductors are enclosed in the same sleeve and cannot be moved physically (see Fig.l)

Impedance, Damping and Load

The lower the output impedance of the amplifier, the less negative influence the Back-EMF can have on the amplifier's circuit)'. Remember that the output impedance consists of amplifier and cable/connector! It is impedance of the entire interface that defines the damping of the diaphragm. In this criteria tube amplifiers fail to deliver accuracy (amplifiers having an output transformer can never provide optimal damping resulting in a corresponding mushy and ill-defined bass reproduction).

For a power amplifier the combination of the above-mentioned phenomena results in a very complex and continuously varying load that is changing dynamically with the frequency and the level of the music signal! Traditional design theory indicates that an amplifier output current capability in the region of 5 to 15A is sufficient, but in actual use peak current requirements of several hundred A are required when driving demanding speakers! It is not unusual to find that amplifiers that are specified for continuous 2 Ohms operation are failing to drive speakers with a nominal impedance of 4 Ohms without noticeable compression, signal damping, limiting or instability effects. At some frequencies some speakers (e.g. electrostatics) however can present a dynamic impedance roughly comparable to a 0.5 Ohms resistance! From this it becomes quite clear that most speaker cables are truly a weak link in audiophile systems.

Fuses, Voltage and Current Limiting

A fuse is non-linear element and any fuse downgrades performance considerably

One of the most critical points is the protection against short circuits. Even today many amplifiers have none. Often fuses are installed in the DC line or in the output with the hope that they will blow before the amplifier is damaged. Other units use voltage or current limiting (some of them "programmable") or a combination of both. This is also unacceptable, because, voltage and current limiting protection circuits are not just triggered when a real short-circuit or

dangerous impedance is present. As they have to react almost instantaneously, they can also be activated by back-EMF, changes in speaker-phase, low impedance loads, etc. When they activate they distort the signal (some even oscillate!), which not only sounds terrible but can also be lethal for the speakers. A well-designed short-circuit protection should not be able to influence the audio signal in any way, but still protect the output stage from true short circuits. So far these contradicting requirements precluded a solution that works in real-world situations. However a rather ingenious combination of elaborate circuitry and ultra-accurate sensing and analysing techniques has made it possible for FM ACCOUSTICS to solve this problem 100%.

It must be remembered that a fuse is a non-linear element and any fuse downgrades performance considerably. Mains fuses do not harm as they are on the primary side of the transformer. But if a DC line fuse or an output fuse is in the circuit, performance suffers dramatically. These fuses contain very small wires through which the entire signal must pass, and this obviously creates tremendous additional resistance. Furthermore, this resistance increases whenever high current is flowing as the fuse heats up to very high temperatures long before it blows. Such non-linear resistance changes should not exist in an audio circuit, in the DC supply, or - worst of all - in the output of an amplifier. Fuses automatically act as compressors/limiters. Whenever a fuse is installed at one of these points, the amplifier has an inherent non-linear element and one can be sure that performance of the unit is compromised.

Summing up, the following guidelines should help to optimize amplifier-speaker interfacing:

If an amplifier has DC line fuses or fuses in the output, its performance will be compromised.
If an amplifier has the usual voltage or current limiting or input or driver-compressing protection circuits it will not be able to achieve ultimate results.
Do not underrate the importance of the quality of speaker cable. It is the weakest link in most audio systems.
Do not simply go for exotic looking cables. They may look good but you want perfect interfacing. Good looks belong somewhere else.
The weight of a speaker cable is a good indicator on how much conducting material is used inside the cable.
When selecting speaker cables make sure you are honestly informed about the square section of the conducting material.
Select cables with individual conductors that allow fine tuning performance.
Fine tune your cables to your system by either keeping the conductors close together, keep them a few cm apart of twist them.
Enjoy gold somewhere else than on speaker connectors.

Favourite Recordings

Monty Alexander; Montreux Live; (MPS)
Stravinsky; Le Sacre du Printemps; CSO/Solti; (Decca)
Getz/Gilberto; Bossa Nova's; (Verve)
G. Pierne; Variations sur des Rondes Populaires; (Reference)
Shostakovic; Lady Macbeth ofMtsensk. Rostropovic; (EMI)
Debussy; Le Martyre de Saint Sebastian; (Erato)
Manuel Ponce; Conderto del Sur
Jimmy Witherspoon/Ben Weber; "Live"; (Verve)
Carol Thompson; The enchanted Isles; (Dorian)
Angela Debarre; Gipsy Guitars; (Hot Club Records)
Various Artists; The miraculous Mandarin; (Bartok)