CHAPTER 1

WHAT MAKES GOOD SOUND?

Good sound is the experience obtained where an electronically recorded musical work can be reproduced in a domestic environment such that the listener is taken back in time to the actual performance. The expected experience seeks to repeat, on more than one occasion, either the performance itself, a repetition of the work or the interpretation of the work. A feeling of "you are actually there" is the intention; and if performed correctly, a warm and emotional feeling is created much as we obtain when attending a concert. If there is no "emotional coupling" then we have not succeeded in extracting the fine details i.e. the microdynamics" of the musical content.

In order to achieve that experience, we have a need to organise the listening room to match the style of the output of the recorded piece so that it complements the performance rather than providing its own contribution. The room should be sonically neutral otherwise it becomes, in itself, a musical instrument that is not intended to form a part of the work.

The electronics and the associated loudspeakers must also be selected and tuned in turn to match the room acoustics if we are to achieve a clear and consistent result. In this case, we are focused upon how to obtain the necessary knowledge and skills required to build an electronic system that can take maximum advantage of the modern day resolution offered by digital media such as the Compact Disk.

To achieve an electronically reproduced sound that comes close to that of a real musical instrument, we need to make decisions regarding the best choice of the technology that will bring us closest to that ideal system. We require the following sonic characteristics if we are to come even close to that objective:-

a) Maintaining the correct timbre of each and every instrument.

b) Balanced harmonic structure actually a part of (a).

c) No changes in pitch caused by the electronics.

d) Emotional coupling i.e. preserving the microdynamics.

e) No smearing nor overhang of musical notes.

Achieving musical sounding systems is difficult and requires complex decisions to be made as to the most appropriate technology to use noting that its operational characteristics must also take into account its relation to the loudspeaker. The complete system is understood to be symbiotic as the electronic function is modified by the interconnecting cables as well as by the loudspeaker system.

The choices are effectively and quite naturally broken down into two types of systems:-

a) high powered systems driving inefficient loudspeakers or,

b) low power systems driving highly efficient loudspeakers.

High powered solid state systems with ratings up to as much as one kilowatt are available and routinely drive loudspeakers having electrical to acoustic efficiencies as low as 2%. Such systems need to use multiple solid state output devices to achieve that level of power. The drawback is that production quality varies from device to device hence, all of the devices have to be matched on a curve tracing machine. Huge numbers of devices are required to allow this hand matching to occur and it is this factor alone that makes it almost impossible to achieve the desired level of sonic quality in a home built system.

High power cannot be obtained from tube based systems unless large numbers of tubes are connected in parallel. Further to that, the topology that can be used to produce more than 350 watts is limited to push pull only. As many as 16 tubes have been used to achieve this level of power and, as noted earlier, the tubes must also be hand selected and matched to ensure that they will operate correctly.

Solid state electronic systems tend toward extreme complexity caused by having to manipulate the signal many times as it is amplified. In the case of tube based systems however, this need not be the case as the circuits tend to be much simpler in nature.

The argument between choosing solid state and tube based designs comes down to having to add complexity to cure problems created by the components used e.g. capacitor induced phase shifts or aiming for a simplistic approach. If we choose tube based designs, there is the further option of using push pull for more power and working into the same type of loudspeaker as a solid state system or, opting for single ended and low powered systems that use a different type of loudspeaker altogether.

If we add the thought that each component adds something to the sonic mix, we come to the conclusion that 'simpler' should be much better than a complex solution necessitating additional circuit elements correcting unwanted sonic anomalies.

An amplification path that consists of one amplifying device, three resistors and a small capacitor is the minimum that can be used on a single gain stage. This effectively rules out a simple form of solid state solution.

Tube based systems can utilise a number of tube types as in triodes, tetrodes and pentodes where each has its uses and application. In this publication we shall be concentrating upon using small and large triodes since they are known to be able to provide the fine details locked into a musical performance, call these the "emotion" if you will because that is what we seek.

Triodes in themselves suffer from a number of shortcomings. The most important one being that they are low powered even when the large transmitting tubes are taken into account. They also require high voltages to operate and this tends to put people off a little. Not everyone wants a large triode in their room and really, it is no different to any other amplifier. There is even talk in some magazine reviews of "death defying voltages in the living room. That type of statement is not much more than technical sensationalism and belongs in the daily newspapers and not a quality hi-fi magazine. Technically, 300 volts d.c. is just as dangerous as 1,200 volts d.c. Reluctance to accommodate such amplifiers is nothing more than intellectual snobbery. A television operates with 25,000 volts and has a tendency to emit soft X Rays but they are not thought of as dangerous. The solution is to cover the amplifiers with cages to prevent access and this aspect of safety is usually a part of product certification.

As a note, all push pull output topologies are fundamentally flawed as the push pull stage, as a so called "virtue" cancels its own 2nd harmonic but retains the remaining and strong 3rd order harmonic. This leaves a "hole" in the harmonic relationships that one can clearly hear as it is no longer pure sound.

If a push pull driver stage is also used, this does the same and, as the resultant is cumulative, the odd order harmonics are no longer truthful in respect to the original overtones created by the musical instrument. In most cases, large amounts of negative feedback are used to "correct" the non-linearities and this serves to create very high order harmonics that are not present in the recorded material. Furthermore, the feedback is extended to encompass the non linearities of the O.P.T. and because of this, any Radio Frequency [RF] signals that are induced into the loudspeaker cables are fed back into the amplifier and can affect the overall reproduction.

The ear perceives this as a change in harmonic structure and tries to match it to its memorised harmonic structures of the instrument. The ear/brain interface will find a reasonable match unless the harmonics are so badly mutilated that the overall sound is distorted however, the processing time required by the brain tends to lead to "listener fatigue".

Push pull designs also cancel the B+ power supply noise created by the rectification diodes but, this noise typically appears all over the circuitry as it is often embedded within the ground rails and does have an impact on the low level signals.

An interesting facet of the way the ear to brain interface works is that an ear can be trained to accept a quite different sound to that of a live musical instrument. In fact, once trained in this type of harmonic relationship, such an ear will recognise a live instrument as being "wrong". This is not uncommon amongst audiophiles as they listen for long periods to music that is not live. It is artificially coloured because of the electronics and by the loudspeaker technology therefore is memorised as such; eventually, with time, perceived and memorised as being "correct".

Another problem arises with the balance of the instruments as most audiophiles want and desire a heavy bass punch coupled with very clear and strong highs. Watch for their disappointment when they hear a live orchestra and can't hear the "bass slam"! Bass slam is an artifact created by a bass content that is over dynamic and over driven in relation to the balance of the instruments. An orchestra has "body" and "weight" as does a concert grand piano. A system that is said to have "bass slam" will reproduce a piano with the lower octaves overblown and will sound lightweight and typically "thin" in the mid range because such systems tend to have a week mid range. Balancing the weak mid range and supporting this with a clean and generous helping of highs will demonstrate the effect of there no longer being any bass slam. This can be demonstrated when using a tri-amped system where increasing the amplitude of the treble amplifiers makes the bass sound thin. Another demonstration of this facet of sonic balance is encountered when using a sub woofer. Altering the balance of the sub woofer content can improve or soften the high notes sung by a soprano. This is not because of the singer but rather a mechanism of the ear and how it processes the various frequencies.

For those persons who suffer from tinnitus also known as "ringing in the ears", push pull systems tend to aggravate the condition. It is quite noticeable that "listener fatigue" and aggravation of tinnitus are rarely experienced when working with single ended systems whether they are tube or mosfet based systems.

A lot of audiophiles look endlessly for a solution with the "bass slam" of a one kilowatt solid state amplifier coupled to the mid range output of a 300B tube. Highs are supported by a 45 tube and this is viewed as THE system of the century. Regrettably, it is not that easy. The difficulty in realising this ideal system is as much to do with the properties of loudspeakers as much as the amplification system required to achieve this.

How do we obtain such a machine that offers all of this? There is no simple answer to that question but, there are some strong indicators such as triodes, which show the way.

Triodes are not, of course the total solution as, to get the best possible bite at the microdynamics, 75% of the total cost of a top quality single ended system goes on the power supplies. Added to that cost, we need to examine the loudspeaker chain as only highly efficient loudspeakers can be used with such low source power. Triodes do though, have one attribute that transistors generally do not have, and that is the ability to convey emotion as in the reproduction of the extremely low signals that are present in music.

Mosfets are the exception as they too can achieve this emotional coupling and it is no surprise to find out that a mosfet has very similar signal transfer characteristics to a triode and operates best in Class A1.

To achieve that level of performance requires careful choices in topology, tube types, power supplies and assembly methods. There is an element of black art in getting it right and hopefully, this book will lead the reader into some thoughts and tricks of the trade as to how to achieve this.

As an introduction to the use of triodes operating in single ended form, an outline is given in the next few paragraphs as a general review of the concepts and thinking required to obtain the best results from triodes.

Triodes work best when they are loaded on the plate with an inductive load such as a transformer. This serves the purpose of maintaining the same d.c. current through the tube as the a.c. load varies where any changes in the current through the tube affects the gain. It can achieve this because a transformer can have a small d.c. resistance e.g. 200 Ohms and a very high a.c. resistance/impedance e.g. 5000 Ohms. If the d.c. current stays constant as the drive varies, then the amplification factor will remain constant also. If the amplification factor changes with the signal then the power transfer is no longer symmetrical; thus distortion in the form of strong 2nd order plus other harmonics is created.

On the other hand, a triode plate driving into a resistive load, will have to work into the same load with almost the same d.c. and a.c. characteristics. Therefore, even the low power transfer characteristic is not symmetrical and distortion ensues. The greater the drive signal, the greater the distortion.

There is always some distortion present when a triode is being driven and this shows up as mainly second harmonic and a little third harmonic which is understood by the ear/brain interface as benign thus acceptable and sometimes called "euphonic". The distortion content increases at higher power levels thus, if the way the tube is driven is held within very small drive parameters, it is possible to operate a triode as a gain stage having acceptable gain but with a tiny amount of distortion.

The best sound is obtained using interstage transformers [I.S.T.] where each stage is operated with at least 6 dB headroom and there are quite simple technical reasons why this is so. For example, there is no grid to cathode current being passed across the two stages as this tends to modify the sonics of the second stage. Also, the 180 degree phase shift caused by the action of the transformer has less of an effect on the sound than the 90 degree phase shift introduced by a coupling capacitor and is why they sound so much better. The 180 degree shift is effectively benign and can be corrected by reversing output wiring or by using another tube stage or transformer. The 90 degree phase shift introduced by a capacitor cannot be cancelled nor removed. By using transformers in this way, music peaks are handled quite comfortably and the end to end distortion of the whole amplification chain can be brought down to as “low” as 0.1 %.

Ignore T.H.D. measurements of 0.00001% as these look wonderful and sound awful. T.H.D. analysis has been discredited simply because it was established as a testing methodology to demonstrate some form of repeatable bench test. Manufacturers drove themselves to reduce this distortion year on year and ended up with that characteristically bleached out, analytical sound that is not music. T.H.D. results, being the sole objective of the Industry for many years could be said to have killed off the High End audio business. But, along comes a S.E.T. system that measures really badly yet sounds wonderfully musical. The Industry, needless to say, has woken up to this fact and has responded with an amazing array of systems that do sound really good.

This book will discuss the design requirements of interstage coupling but the main focus is on using very high quality Teflon and tin foil coupling capacitors to achieve a similar result but with far less complexity.

The other area that requires an in depth understanding is the power supply. A triode should always be operated in Class A1 where it conducts at full current at all times. When driven with a signal, if the plate d.c. and a.c. loading is correct, the current drawn from the power supply should remain the same although in practice, it does vary a small amount. The consequence is that the power supply has to deliver full rated power at all times. But, as it is in series with the output stage, it has to have a fast transient response and adequate power reserves hence the high cost.

One notable aspect of operating triodes into a set of horn loudspeakers is that the trade-off is between low amplifier efficiency versus highly efficient loudspeaker technology. One watt of source power into a 110 dB/W/m horn is not much different in actual acoustical loudness to 250 watts into an 88 dB/W/m bass reflex unit. As stated, the power supply is in series with the output stage tube plate and the output transformer load therefore, the individual qualities of the power supply components have a quite direct impact on how the amplifier sounds, the "sonic" quality as we call it. Designing a clean sounding power supply is difficult and tedious but not impossible. Designing a clean sounding 1500 volt d.c. supply is a real challenge but it is done.

Another key consideration in listening to music is the fact that the first milliwatt is where the microdynamics are to be found therefore, the first design objective is to bring the system noise down to the absolute lowest possible level. Low enough in fact, to where even the Johnson noise generated by each and every component is all that is left to be heard. Even that can very often be minimised through using two resistors in series in order to reduce the voltage across them thus halving the Johnson noise.

As a contrast, a high power amplifier working into inefficient loudspeakers will need lots of watts to make a driver cone move and as a consequence, they very often have quite high levels of residual noise making it almost impossible to recover the low level dynamics of the music. It has also been stated that a solid state system delivers its best watts as the final watts whereas a S.E.T. delivers the best watts as the first watt.

One strange aspect is that triodes inter-working to horns require such low power that the loudspeaker cables can be really thin as even the loudest music passages will see only milliamperes flowing down the cables. Single strand silver cables can be used and they are considerably less costly than some extremes of connecting cables that are on offer in the marketplace.

Another aspect of the efficiency equation is that a complete system can be operated from a single a.c. power socket since the power consumption is so low even when using the Class A1 operating mode.

A conclusion that can be drawn from these aspects of single ended triodes (aka S.E.T) is that the cost of ownership of a total system of amplifiers and horn loudspeakers can be balanced against the extreme cost of the supporting hardware needed to make solid state systems function well.