A Word about Speakers and Single-Ended-A-Triode Amps

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A historical approach

During the old days of tube audio, speaker systems were quite simple. Mostly there was only one full-range driver in a cabinet, which was open at the rear or the driver was mounted on an open baffle. There were legendary speakers in Europe, which followed this recipe.

However, why they were sounding so good?

- The diameter of the speaker cone was big.
- The sensitivity was very good.
- The linearity of the impedance was good.
- No speaker dividing networks (XOVR) produced any phase or impedance problems.

Why did they disappear during the decades?

- Solid-state amps came along.
- The formulas and calculations of Thiele and Small (TS) made it possible, to give a speaker predictable characteristics, while giving better bass response in closed or bass-reflex cabinets.

Why does this only work with solid-state amps?

This is no question or a decision between solid-state or tube design, but only a decision between (severe) negative feedback (NFB) or no one at all. The difference between both approaches is that an amp with no NFB shows rather the characteristic of a current source, while applying NFB makes it more and more a voltage source.

Speakers - using soft edge and low sensitivity drivers, designed according to TS calculations NEED a voltage source to function properly. Current sources are NOT recommended!

What is a current source?

A current source is a circuit, which translates the input voltage to a regulated output current. The load only determines output voltage …

$U_a = I_a * R_{load}$

What is a voltage source?

A voltage source is a circuit, where the voltage is regulated at the output according to the input, while the output current depends only of the load.

The most severe example of a voltage source is that of the OP-Amp: It shows a voltage amplification factor of more than 10 million (that reads 1µV => 10V) if not feed-backed (open loop) and with NFB applied, it will be able to shut amplification down to 0,00001 (that reads 1V => 10µV), because there will be the boundary between signal and emitted noise. The voltage source model can therefore be applied to a range of about 10^7 to 10^9 –

dependant on the type and the facilities – in a useful way. That makes it easy for developers to design circuitries.

Nevertheless, NFB has also big drawbacks:

- It cancels out even harmonics – during amplification as well as subtraction from the original input signal.
- Odd harmonics are the ones that stay (awful !!!).
- Capacitive load conditions can bring stability problems (ringing, oscillations).

Designers of the Fifties found out – that

- Amps with no or really weak NFB sound best.
- Single ended amps do best work, although they show very little power efficiency (electrically spoken).
- All kinds of NFB, symmetrical designs, balanced designs and even push-pull designs show the same problem => cancelling of even harmonics.

Even harmonics esp. k_2 (twice the frequency of the basic tone), are the base of good sound:

- They give you the ability to distinguish between a Stradivari and a more common violin.
- They help to improve dimensional listening. Most of the imaging of a well-designed amp-speaker combination depends on how good k_2 is processed.
- They help to improve articulation and understanding of speech.
- If cancelled, an overdriven electric guitar will not sound cute anymore!
- Recording engineers know about this fact, so they use "Aural Enhancers", which in fact do not anything else but adding even harmonics to the recorded sound.

The big bargain of a SET-A amp is, that they do not need overall NFB. They behave commonly as a current source, which means - theoretically spoken - they translate the input signal voltage into an output current showing the signal integrity of the input voltage.
The I/U conversion is done by the load (speaker), very similar to that of a current output DAC. We also see, that this circumstance will need load impedance, which is highly linear and/or not prone to phase shifting. Again theoretically spoken - a purely resistive load will show best results. Such a speaker-load will not be easily achieved, but there are some very good approaches.

The impedance problem

- A single driver, mounted to an open baffle of ample area, will show a rise of impedance at its resonant frequency point on the bass side and afterwards following it will show an area of linear impedance (nominal or typical impedance, e.g. 8 Ohms) if we increase frequency. Behind this linear area, it will show a slight increase in impedance the more frequency increases.
- A two-way system of drivers will show similar results, but will show irregularities at the jointing frequency (Woofer/Tweeter) of the XOVR. These irregularities will increase, the higher the order of the XOVR becomes. It can be said, that a first order XOVR is better from this point of view, than a third or fourth order XOVR. Worst are

acoustically matched filters within a XOVR, because they will ONLY work with voltage sources showing extremely low source resistance. That means they will work ONLY with amps, having severe NFB applied.
- The more ways in a speaker system – the more problems you will have with impedance linearity!
- Impedance problems in a – say two-way – speaker system can be solved but not turned away completely.

The phase problem

- Mostly all I pointed-out within the preceding chapter about impedance problems may also be applied to phase problems.
- The phase of a single driver, mounted to an open baffle of ample area, will show a rise of phase shift in reactive direction the more frequency increases. This is due to the inductive resistance component of the voice coil.
- Again, filters of any kind will lead to irregularities within the phase response.
- Because phase irregularities harm a voltage source (showing extremely low source resistance) only if they tend to become capacitive (ringing will be the result), most speaker designers ignore this effect.
- Phase problems cannot be solved any easy within a XOVR-driver-cabinet combination like impedance problems because they usually affect the acoustic response of the combination.
- Components, that should linearize impedance within a speaker combination may (mostly will!!!) increase phase problems! So please be careful!
- Any closed, bass reflex or transmission-line design will show individual phase problems because of the interaction between the cone and trapped air, volume of the cabinet, tunnel dimensions, wavelength and/or runtime effects and electrical parameters.

A word about matching

- When solid-state amps came along during the Sixties, they nearly always showed severe NFB. This is due to the fact, that bipolar transistors show high amplification factors while also showing a broad spread of their characteristics. In addition, the temperature influence is very high. All this can be tamed only by applying heavy NFB. From this point of view, the NFB helps to make circuitry stable.
- At the same time, also tube amps for use in home audio systems were built using NFB. Because tube circuitry is less prone to the before mentioned behavior, it needed not so much/severe NFB. The result was better sound. Almost all designs used a push-pull configuration of power tubes at the output, so the refuse to apply NFB could not really increase the sounding capabilities.
- Both designs use NFB for to solve stability issues and to lower overall harmonic distortion (THD). NFB cancels out even harmonics, which are the highest percentage in the THD figure, so the selling factor increases if a product can be merchandized with a very low figure. Nobody from the industry will tell you, that then the figure left is only odd harmonics!
- HiEnd-Audio tube amps at any time tried to come along avoiding NFB as well as push-pull configurations. Therefore, they show the best sounding capabilities but not showing lowest THD figures. 10% of k_2 at full power output is no uncommonness to a SET-A amp – then and now. Anyhow – like said before, this will

increase sounding capabilities but maybe not increase merchandizing to people who do not know about.

- SET-A amps are best matched with speakers of high impedance and phase linearity and good sensitivity. Single-driver speakers needing no XOVR will show best results. However - such systems are expensive! If you cannot afford such a system, you could use as a second best choice a coaxial driver, but then you had to design the needed XOVR in a way, that impedance and phase problems are kept to a minimum.
- Best cabinet choice will be a back loaded full range horn, because it will support bass response to a maximum while leaving enough pressure to the backside of the cone, so the full range capabilities of the chosen driver will perform at their best.
- Second choice will be a so-called "cut resonator" design. This is a bass reflex cabinet, where the port is coupled to a horn, leading to the outside. This design is not so renowned today but was used in the older days very often in home audio designs as well as in professional instrumental stage boxes, cinema sound and PA systems. It shows a little lower overall sensitivity than a full range horn, so only drivers with very high sensitivity should be used (100dB SPL or even more). Unfortunately, today there are not so many drivers on the market, which are usable for such a design (!).
- Third choice will be an open baffle or a design where the rear of the speaker is open to the outside. Rear-open speakers show a similar behavior like open baffles, but will increase bass according to their construction. Design has to be done in a way, that enough pressure will remain to the back of the cone, that it will show best full range performance.
- Closed speakers or bass reflex speakers are not quite usable designs, because they tend to lose all the bass or even never had good sensitivity due to the usable TS parameter range of such designs. Please keep in mind that the parameter range (e.g. of Qts) is very narrow, to build a good closed design. All drivers in the market meeting these parameters will have a soft rubber or foam edge and so they will show low sensitivity and very low high frequency response – not useable for a full range design! Only drivers with stiff, hard paper or resin filled fabric edge will show good high frequency response and good sensitivity. The initial design of such drivers will not need trapped air within a cabinet for repositioning of the cone. This is achieved by mechanical force only, while current through the voice-coil does the rest in leading the cone. In addition, it must have dual cone design for delivering bright treble response.
- Big cone areas lead to better bass response.
- Coaxial drivers using treble horns are a very good choice but please keep in mind that the XOVR has to be designed very thoughtfully and clean. Many sophisticated audio designers worldwide made it a lifetime project to make this possible – so please be aware of this instance!

The sensitivity of speakers

As I wrote in my article about "Modding the Music Angel 845", 95dB SPL are a minimum for a well-suited speaker matched to SET-A amp. The more - the better! Because high sensitivity always comes along with high price you must decide, how much money you could spend for them. Not in all cases, high price brings predictable high performance, so you should chose the model well.

In common it can be said, that the highest sensitivity will show the highest resolution in sound. If you are a fan of Jazz Music, you know what I mean: It is not common to even highly priced speakers, that a brass section can be recognized as several instruments instead a broad summing sound of all of them - or - a choir can be heard as separate voices instead the sum of it. Female voices in an opera recording also will show very hard to solve problems for a speaker, if you want to reproduce them in a natural way. Woodwinds will make the same problems.

If you design your speakers by yourself, always look for a dual cone, full range or a coaxial driver of best sensitivity. Keep thinking about a full range horn (if your physic and math skills allow) or follow a well-known and fully developed project.

If you want to buy your speakers, the air is becoming very thin. There are only a few speakers in the market, which will fulfill your demands. In this case, you should better visit a HiEnd-Audio show and chose a speaker you like and which you may trust in. Always insist on a performance in connection with your own SET-A amp!

Best matching solutions

A SET-A amp needs a speaker with a behavior I described in the preceding chapters. If you want to match this kind of amp with anything other, you should be aware of having many drawbacks. If you intend to use your SET-A amp AND already own speakers and of this "any other kind", you should look for a customer to sell the speakers. The other way around you could also sell the SET-A amp. A transistor amp of good make, quality and power will meet your "any other kind" speakers better, because it will bring you better sound to your home.

If you are seeking for the best sound reproduction possible AND start-up your HiEnd-equipment, please follow my advice and you will own one of the most beautiful sounding systems in the world. I know that many of you will call me arrogant for this last sentence, but I am confident, that you will be straight to my opinion if you should try this recipe.

In this particular case of HiEnd-Audio reproduction, the number one speaker of your audio magazine will not be the best choice, while their number one solid-state amp will also not be the perfect partner for a high sensitivity full range horn speaker.

Full range horns, cut resonators and open baffles will be big furniture at your home. Be aware also, that a living room will also need at least 35m^2 to perform well with this type of speakers. Do you have that ample space?

Everything has to be selected carefully!

My own home audio system consists of:

- DUAL CS701 direct drive turntable equipped with anti-resonant magnet suspension tone arm and ORTOFON M20E pickup (elliptic diamond tip).
- CD player SONY CDP-XE300, equipped my genuine JFET_CDout ("Fetishizator") circuit.
- Tape deck AKAI CS-M3, all audio circuitry taken out and substituted by my genuine JFET "STC" circuitry.
- Tube RIAA and line preamp "TEQUILA" of my own construction and manufacturing.

- SET-A tube power amp MUSIC ANGEL 845, modded and tuned according to my article.
- Full range horn speakers of my own construction, manufactured by a very able carpenter among my many friends. Driver is a 12" dual paper cone full range OEM, no XOVR, 108 dB SPL sensitivity. Horn length is 270 cm and mouth is 70 x 40 cm. Overall dimensions (HxWxD): 105 x 45 x 65 cm. Very beautifully made furniture quality boxes, surface mahogany dark red! (Driver alternatively ALTEC, TANNOY, …)
- GUZI pure silver audio interconnects from all signal sources to the preamp.
- Mil grade RG58 copper audio interconnects of my own manufacturing from the preamp to the power amp (each 8 m long).
- Speaker cables of my own construction and manufacturing are made of 3 wires 1,5 mm^2, loosely braided arrangement, where the third wire is only connected at the speaker side to the ground wire, leading to a compensating line. Length each 4 m.
- Each tube is equipped with two dampers (high temperature resistant silicone rubber O-rings).

My many audiophile friends call this system the best they have ever heard …

If you have further questions, please contact me at: support@tubeclinic.com.

