Preface

The today's (2008) audio (or low-frequency) amplifier world is nearly 100% "contaminated" by silicon solid-state components that ensure proper amplification for any signal from any source (CD, DVD, Vinyl, MP3, Radio, TV, etc.) to ones ears. A broad range of design supporting literature[2] and other information sources and tools like eg. the internet or component producer's applications help design engineers world-wide to come up with the right products at the right time on the right markets - hopefully.

The percentage difference between 100% and nearly 100% is filled with gain making elements that are far away from silicon: vacuum valves and audio transformers. It's an interesting fact that still many CD and/or DVD producing studios work with valve and transformer driven equipment like eg. the compressor types Teletronik LA-2A or UREI 1176LN or they bring into action valve driven microphones (eg. Neumann U47 or Rode Classic II) and mixers at the front-end of the recording chain. Not to forget all the valve powered measurement equipment (from eg. Brüel & Kjær, Tektronics, etc.) still in use.

Because of their outstanding sound quality (eventually mainly caused by an even harmonics distortion effect) most of the involved valves in pre-amp stages are triodes or pentodes configured as triodes. I won't debate whether silicon or vacuum sounds better - this would be purely subjective. But the world-wide growing sales revenues for vacuum based sound and reproduction equipment is an astonishing thing for me and gives a sound related answer by purse or credit card. And another thing surprises me as well: despite the totally different analogue world there are enough young engineers (and senior ones - of course) of our totally digital era that are willing to struggle with such an old fashioned technology by creating superb sounding electronic instruments.

Although it might look as if - but it has nothing to do with Black Art! It's simply the transfer of a specific know-how into life by enthusiasts. A know-how that seems to be no longer part of training courses of universities and colleges, that is threatened to get lost if we don't work hard to stop this evolution by bringing out ready and easy to use modern literature and software tools.

Therefore, the following chapters offer formulae to calculate certain building blocks of valve amplifiers - but for pre-amp purposes only. In nearly all cases detailed derivations are also given. All what's needed are the data sheet figures of the triode's ($_t$) mutual conductance $g_{m.t}$, the gain factor μ_t and the internal plate resistance $r_{a.t}$. To calculate frequency and phase responses of gain stages the different data sheet presented input and output capacitances have to be taken into account as well.

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2 Inter alia: "Electronic Circuits", U. Tietze, C. Schenk, 2nd edition, Springer 2008, ISBN 978-3-540-00429-5

It must be pointed out that all formulae are based on certain assumptions. The most important one is the one that defines the DC biasing conditions of these active devices. The conditions were assumed to be those of the A-class operating point settings: the plate DC current never switches off for positive and negative parts of the input signal. In other words: the A-class operating point is located in the (~middle of the) most linear part of the V_g / I_a versus plate voltage V_a diagram of the respective valve. This is the only way to guarantee that the triode's data sheet figures for mutual conductance $g_{m.t}$, gain μ_t and internal plate resistance $r_{a.t}$ can be taken as so-called constants (always valid: $\mu_t = g_{m.t} \times r_{a.t}$) and can be used for our calculation purposes.

Other biasing classes (B = total plate/cathode current switch-off for negative signal parts or AB = a tiny quiescent current is allowed to flow through plate and cathode for negative signal parts) or the use of other operating points on the V_g / I_a versus plate voltage V_a characteristic plot need certain additional measurements or graphical approaches to get the right values for the above shown valve constants. Having gone through these processes the newly generated $g_{m.t.new}$, $\mu_{t.new}$[3] and $r_{a.t.new}$ figures should be used for further calculation purposes. The given formulae won't change and will look the same.

I do not dive into the valve's DC biasing mechanics because they can easily be studied with the help of a broad range of literature[4]. But in that range of books and magazines[5] I miss a summary of all the gain producing possibilities of triodes on one spot. That will be the only matter of the following pages. The respective formulae were derived from equivalent circuits by application of Ohm's[6] and Kirchhof's[7] laws. It will be demonstrated in detail in Chapters 1… 4. These approaches lead to certain amp building blocks around one valve. The formulae for gain stages that incorporate more than one valve (eg. SRPP or cascoded gain stages, etc.) will mostly be derived from these building blocks.

In addition, MathCad[8] (MCD) worksheets as a part of each chapter allow easy follow-up and application of the respective formulae for any kind of triode. The calculations show results with 3 digits after the decimal point. The only reason for that is to demonstrate - from time to time - (tiny) differences with other calculation results. In reality, even a calculation result of one digit after the decimal point wouldn't present the whole truth because the tolerances of valves are a magnitude away from precision. But this fact didn't - nor doesn't it today - prevent engineers from designing extremely precise working analogue amps and other electronic valve driven devices. That's why, on the other hand, the calculation approaches offered are not far away from reality. For fast estimations many rules of thumbs are offered too.

I'm sure I only did treat a limited selection of possible building blocks for triode driven amps. That's why all readers are invited to not hesitate to send to the editors their know-how on additional triode amp stage solutions - including the mathematical derivations that are needed to understand how they work (à la the presented MathCad worksheets). This book should become the collection of everything what's of interest on this specific design field. The next edition will come out with these additional designs.

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3 in contrast to respective "on dit(s)" a change of the bias point also means a change of μ_t; it is not a constant at all (see also Chapter 16 plots!)
4 Inter alia: "Valve amplifiers", Morgan Jones, Newnes, ISBN 0-7506-2337-3
5 Inter alia: "Tube Cad Journal"
6 a) 1Ω *1A = 1V or - generally spoken - R*I = V
7 a) The sum of all currents in a circuit's node equals zero;
b) The sum of all voltages (= potential differences) in a circuit's closed loop equals zero.
8 MathCad is a registered trademark of MathSoft Engineering & Education Inc., since 2006 part of Parametrics Technology Corporation (PTC), Ma., USA

To sum-up the aims of this book:

- building up a collection of triode amp stage alternatives with satisfactory mathematical demonstration on how they work via derivations and transfer functions,

- to make things less complex the transfer functions are derived from rather simplified equivalent circuits, thus, saving a lot of energy by paying for it with tiny frequency and phase response errors, especially at the ends of the audio band,

- it’s always better to calculate first - and spent money for expensive components later - instead of playing around with dice-type trial and error.

http://www.springer.com/978-3-540-69502-8

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