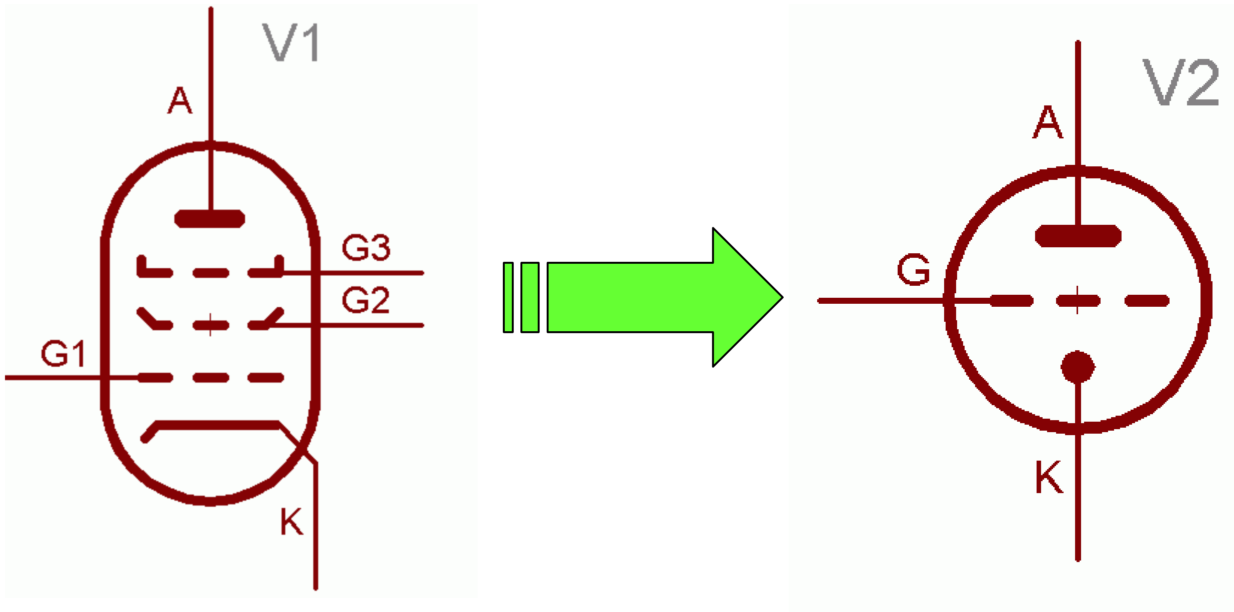
Pentodes *connected as Triodes*



by

Tom Schlangen

ETF 06
Triode Centennial

About the author

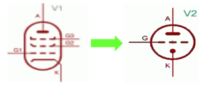
Tom Schlangen

- Born 1962 in Cologne / Germany
- Studied mechanical engineering at RWTH Aachen / Germany
- Employments as „safety engineering“ specialist and CIO / IT-head in middle-sized companies, now owning and running an IT-consultant business aimed at middle-sized companies
- Hobby: Electron valve technology in audio
- Private homepage: www.tubes.mynetcologne.de
- Private email address: serpentine@netcologne.de

Reasons for connecting and using pentodes as triodes

Why using pentodes as triodes at all?

- many pentodes, especially small signal radio/TV ones, are still available from huge stock cheap as dirt, because nobody cares about them (especially “TV”-valves),
- some of them, connected as triodes, can rival even the best real triodes for linearity,
- some of them, connected as triodes, show interesting characteristics regarding µ, gm and anode resistance, that have no expression among readily available “real” triodes,
- because it is fun to try and find out.



How to make a triode out of a tetrode or pentode again?

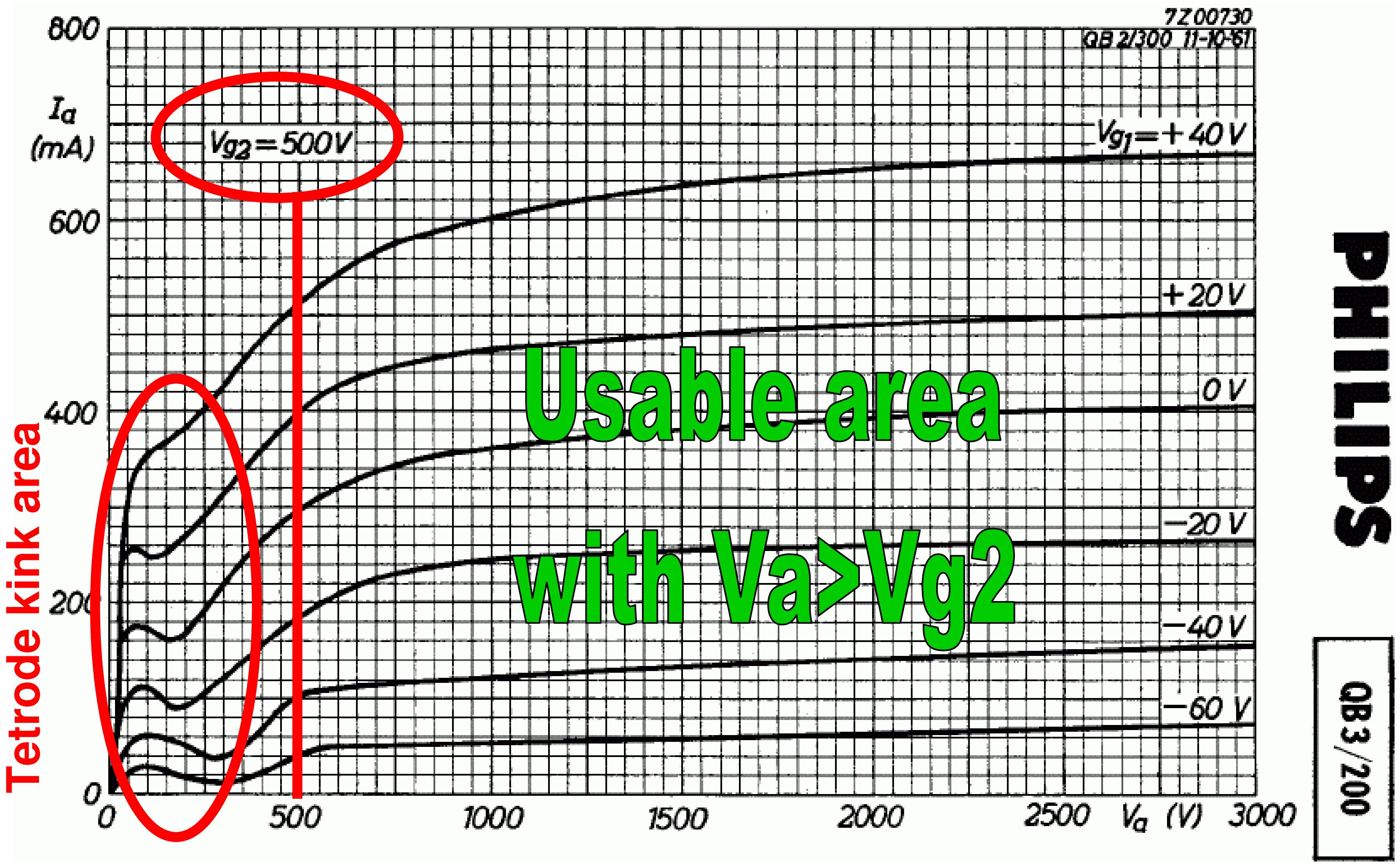
Or, what to do with the “superfluous” grids?

- All additional grids serve a certain purpose and function – they were added to a basic triode system to improve the system behaviour in certain ways, for example efficiency.
- We must “disable” the functions of those additional grids in a defined and controlled manner to regain triode characteristics.
- Just letting them “dangle in vacuum unconnected” will not work – they would charge up uncontrolled in the electron stream, leading to unpredictable behaviour.
- We must look somewhat closer at each grid´s function, to find out how to reverse their functionality back to triode operation in the best way.

Function of the screen grid

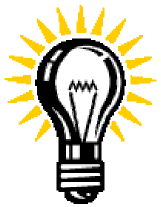
- One of the principle problems of the triode is interelectrode capacitance, especially between anode and control grid.
- $C_{a\text{-}g}$ is a path transferring energy back from the anode (output) to the control grid (input), thus reducing efficiency. This effect is mostly dependent on $C_{a\text{-}g}$ value and stage gain and is known as “Miller effect”.
- The screen grid was invented to electrostatically shield (or screen) the anode from the control grid, reducing $C_{a\text{-}g}$ massively.
- It also can be used as an additional control grid.
- An electron tube with four electrodes is called tetrode.

Tetrode characteristics – fixed screen voltage



Tetrode problems

- “Tetrode kink” due to secondary emission electrons from the anode, attracted by the screen at $V_{g2} < V_a$.
- Unstable operation at $V_{g2} < V_a$. Usable operation conditions are limited to $V_a > V_{g2.}$
- Suboptimal efficiency, but still much better than a triode, especially at high frequency.



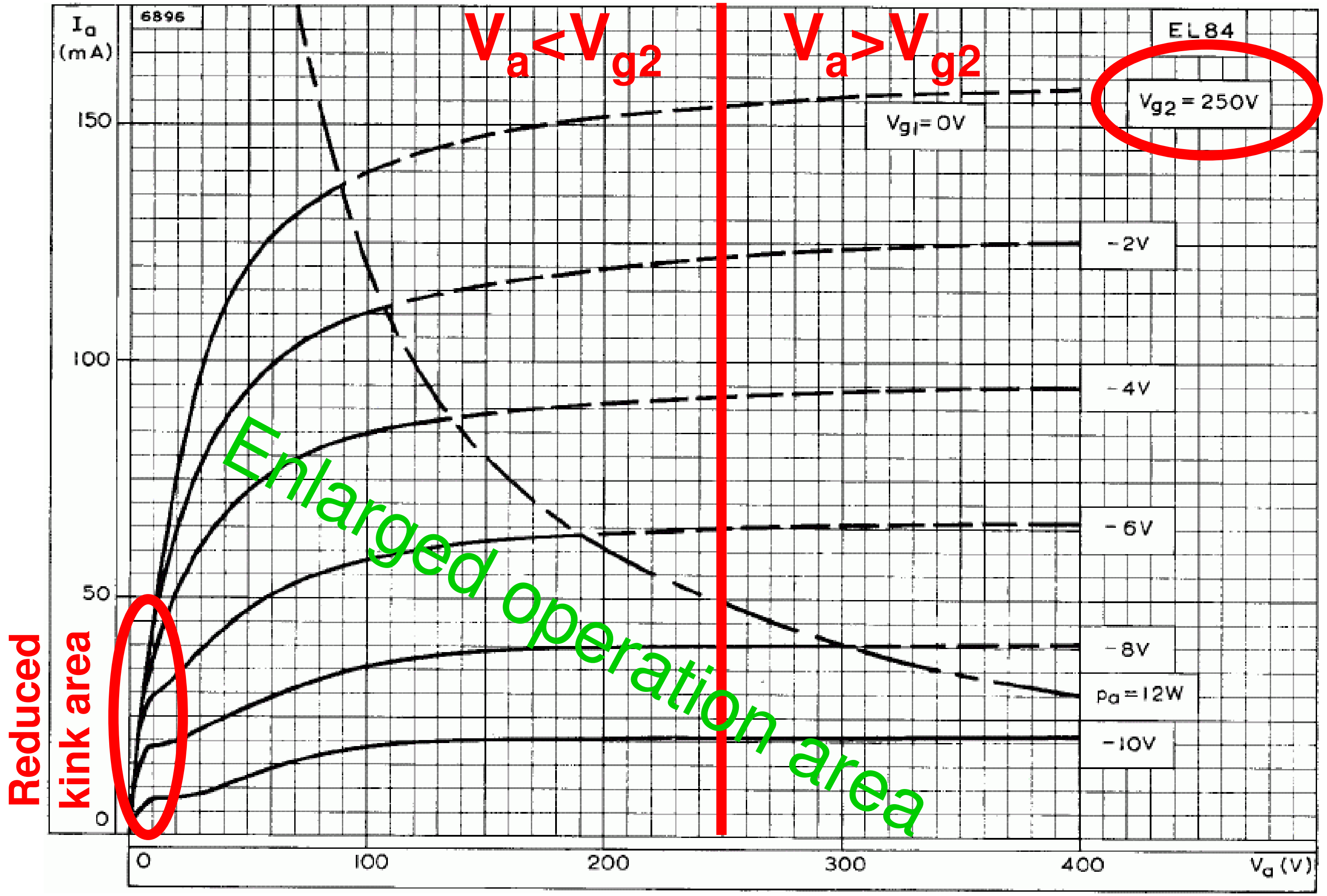
A third grid, the suppressor grid, was introduced.

Function of the suppressor grid

Another grid we must care for…

- Very wide meshed and negative to anode and screen grid, it has very few influence on fast travelling electrons on their way from cathode to anode – they just “pierce” through the weak electrostatic field.
- But its weak electrostatic field is strong enough to repel slow moving, low energetic secondary emission electrons to the plate, blocking their way to the screen grid, thus preventing negative effects (KTxx: “Kinkless Tube”) further enhancing efficiency.
- It also can be used as an additional control grid.
- An electron tube with five electrodes is called pentode.

Pentode characteristics – fixed screen grid voltage



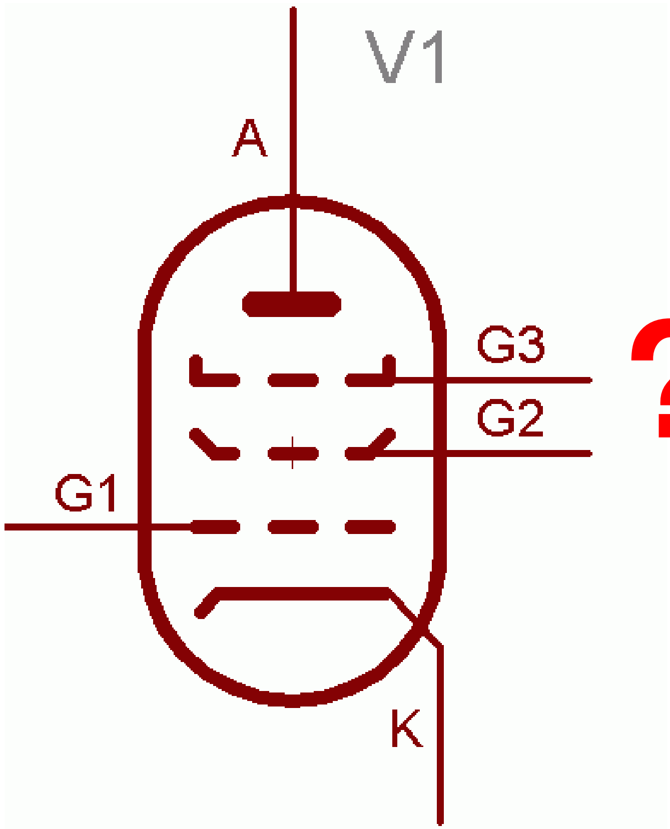
Beam power valves

A special case to circumvent the pentode patent

- Beam forming plates are used instead of a suppressor grid. They work by forming a concentrated electron beam, which also prevents secondary emission electrons to travel from anode to screen grid.
- To maintain their function, beam forming plates *must* be at cathode level. Usually they are connected to the cathode within the valve internally – no separately accessible pin.
- Thus, beam forming plates *cannot* be used as an additional control “grid”.

Where to connect what?

…. to get triode characteristics, again!



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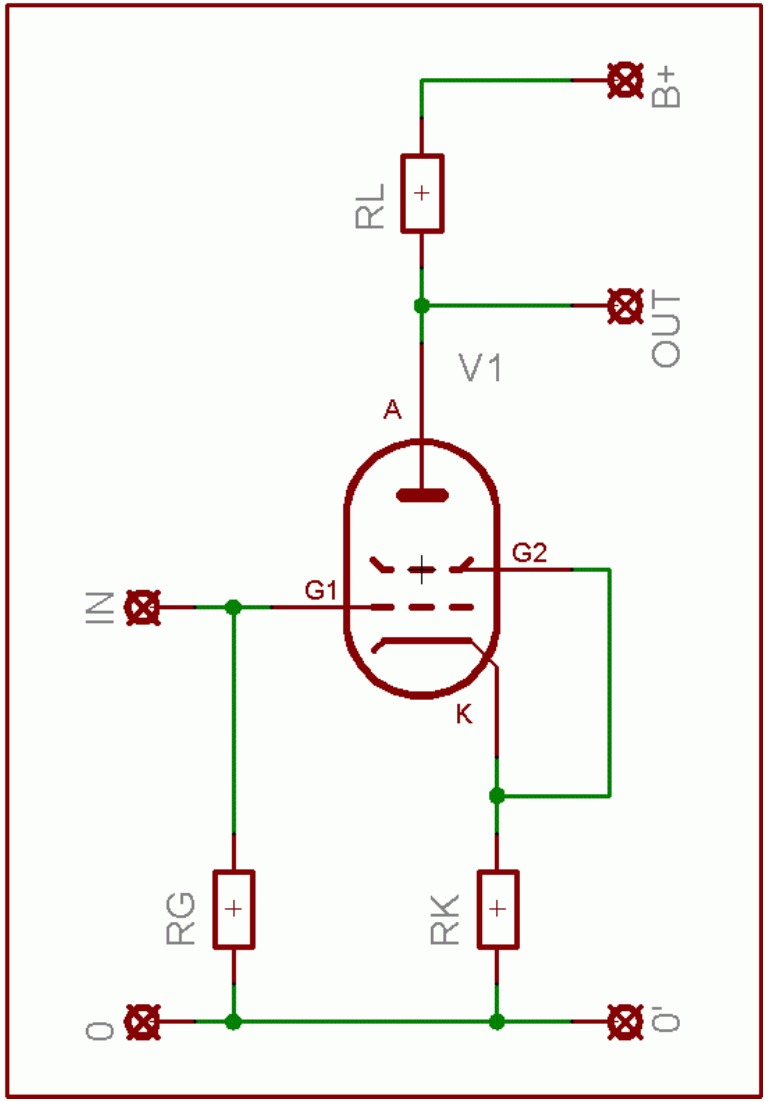
Possible screen grid connections



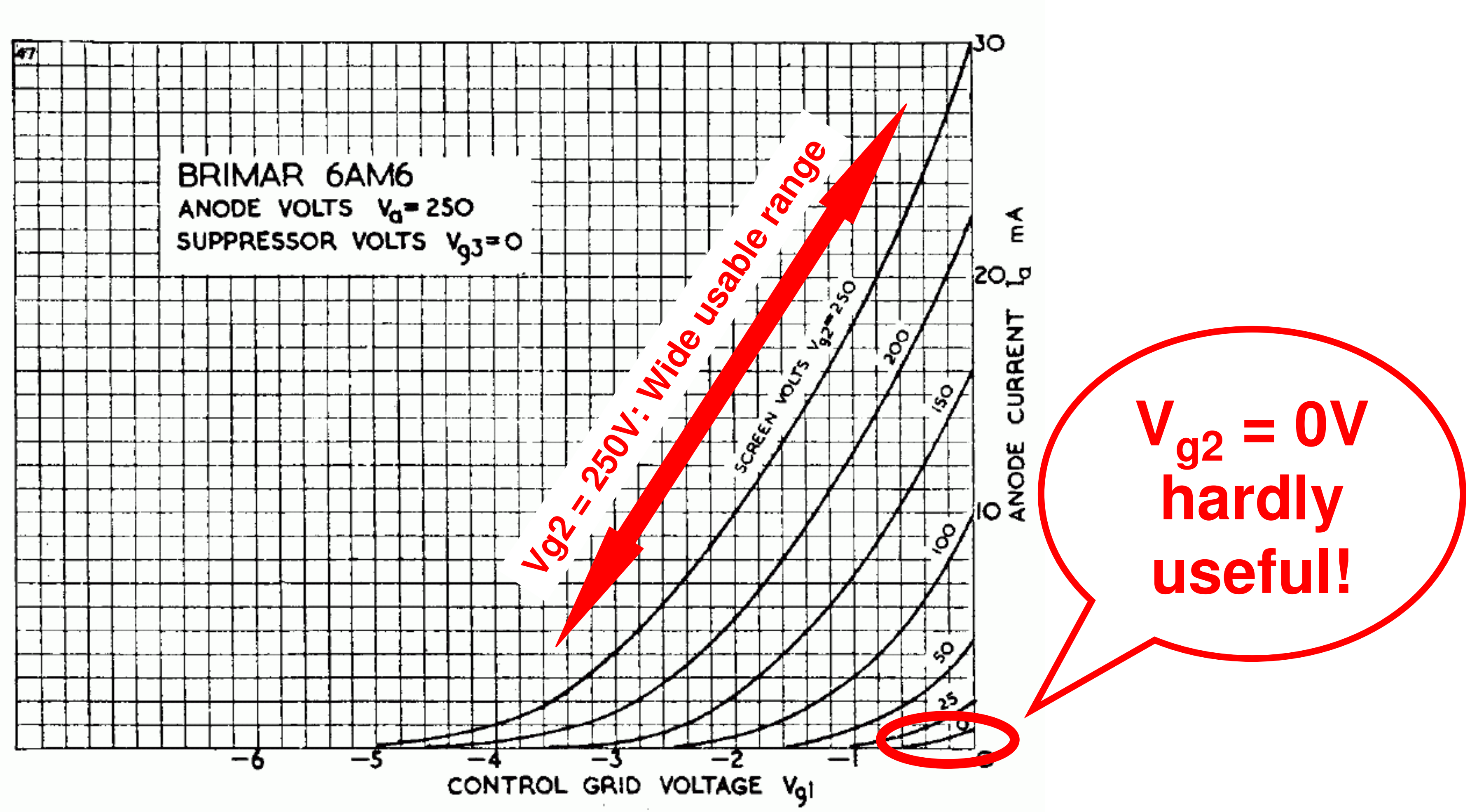
Possible screen grid connections

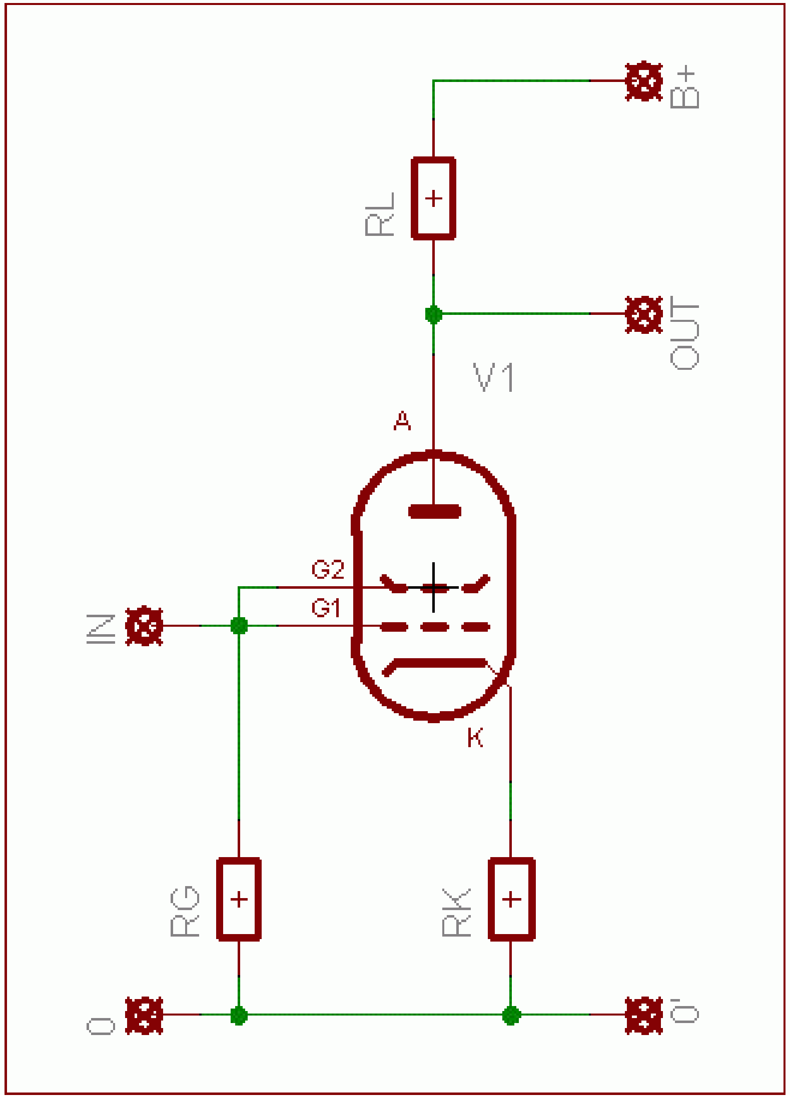
Screen grid connected to cathode

- Special case of tetrode operation: V_{g2} just lowered to cathode level
- Combined g1 + g2 control action is of multiplicative character
- ➡ Valve is almost shut down

Screen grid connected to cathode

(Grid family characteristics shown)

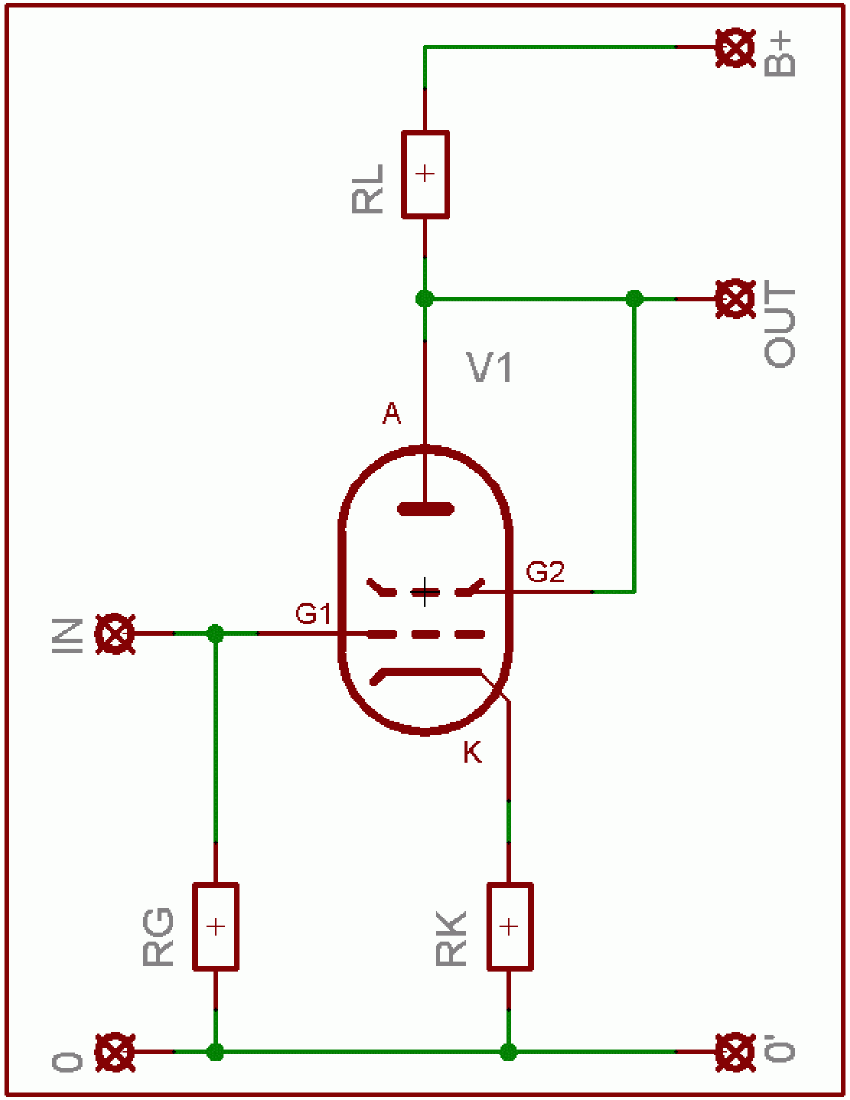




Possible screen grid connections

Screen grid connected to control grid

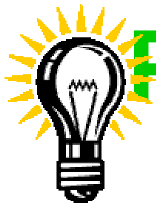
- Again, combined g1 + g2 control action is of multiplicative character
- ➡ Extreme μ, but also extreme internal resistance
- ➡ ”Current trickler”, only useful for few very special applications



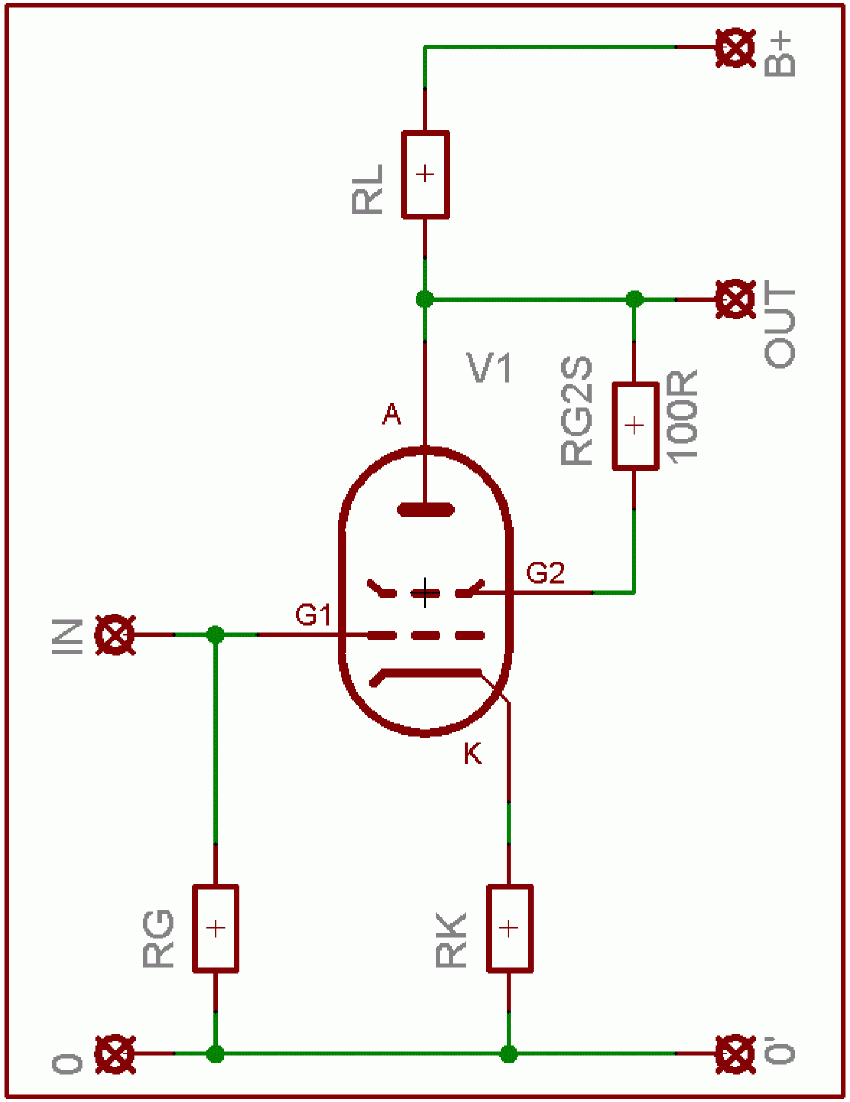
Possible screen grid connections

Screen grid connected to anode

- Screen grid voltage is not fixed anymore, but swings with anode
- ➡ Screen/shielding function of g2 is disabled
- ➡ Screen grid area effectively added to anode area



Preferred method to connect g2!

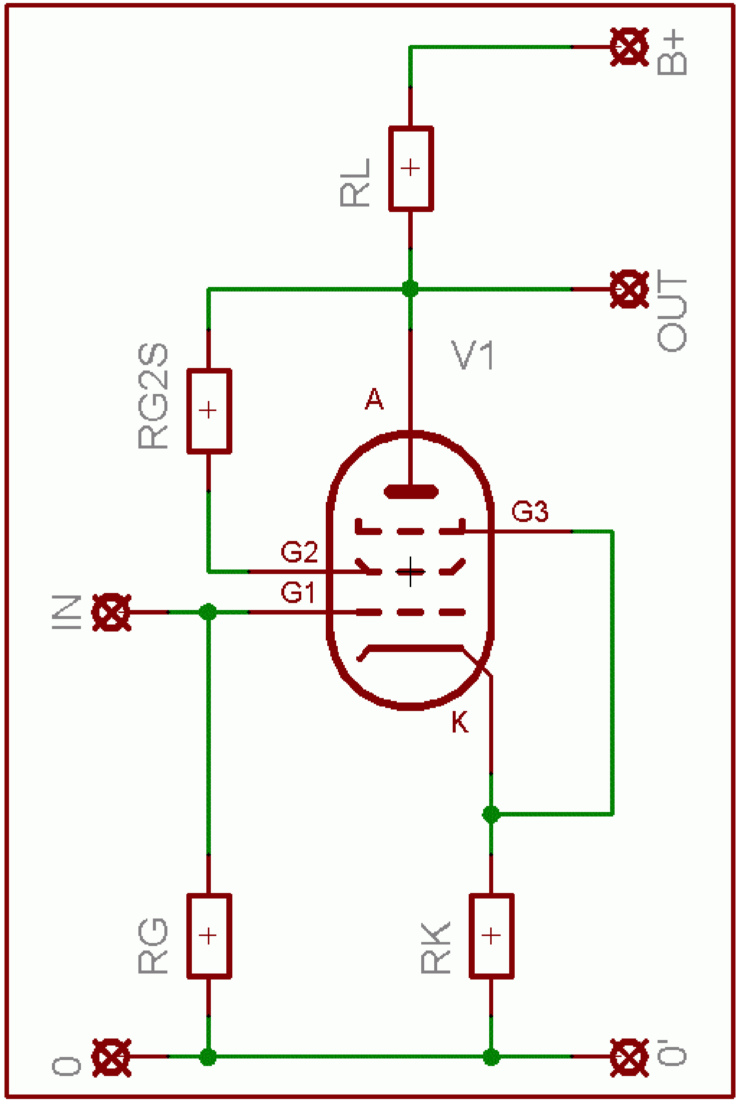


Possible screen grid connections

Screen grid connected to anode

- Usually, a low valued „grid stopper“ resistor is added to prevent parasitic oscillations
- <u>Common misconceptions:</u>
- The purpose of this resistor is *<u>not</u>* to limit screen current (it hardly does, except when blowing like a fuse)
- The purpose of this resistor is *<u>not</u>* to keep Vg2 below Va (there is no reason to do so – wouldn´t work in a linear manner using just a resistor)

Possible suppressor grid connections

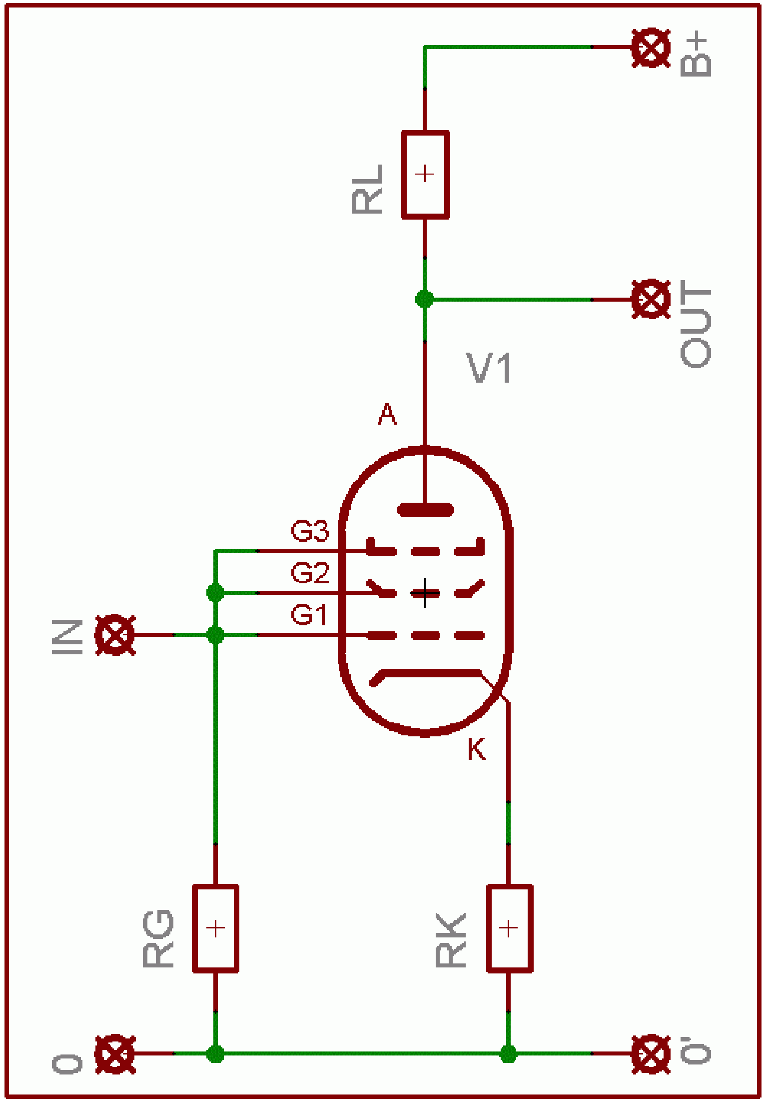


Possible suppressor grid connections

Suppressor grid connected to cathode

- Normal way the suppressor grid is connected / operated in a pentode
- Does not do harm in triode mode
- For beam power valves, usually there is no choice to use another connection, since g3 is permanently connected to the cathode internally

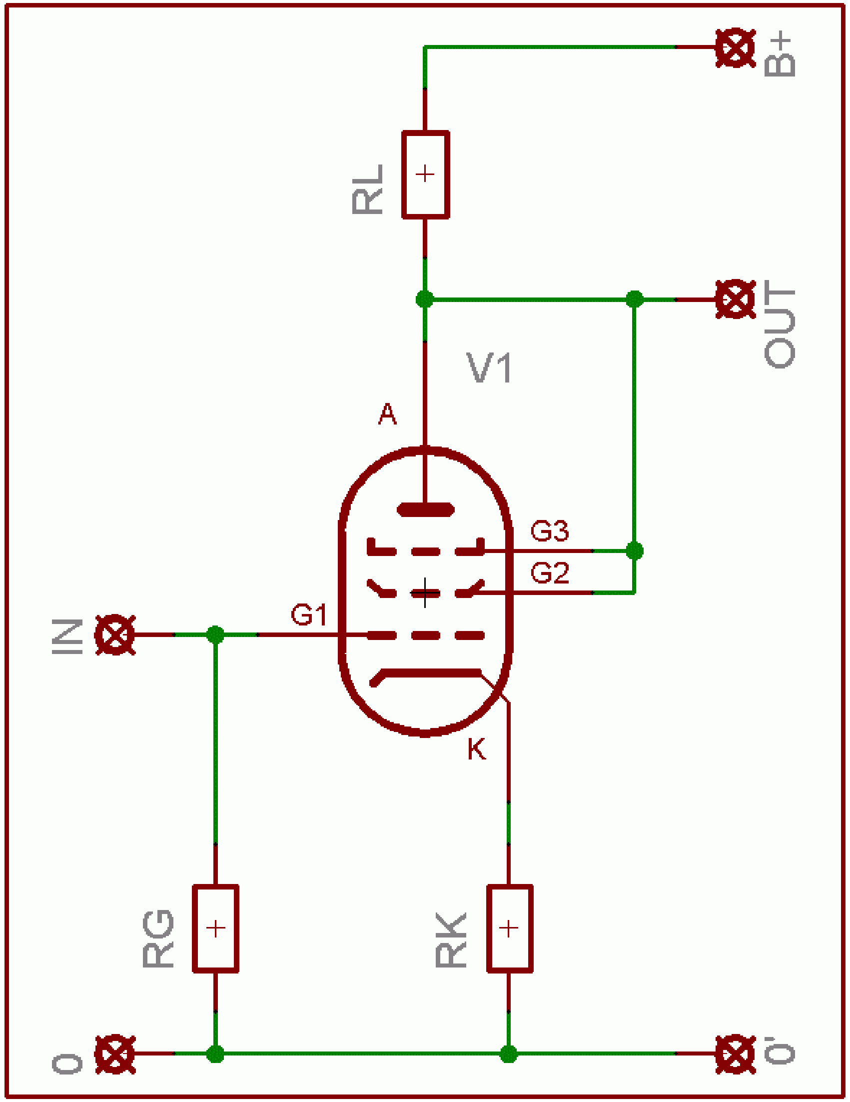
Preferred method to connect g3!



Possible suppressor grid connections

Suppressor grid connected to control grid and screen grid

- Combined g1 + g2 + g3 control action is of multiplicative character
- ➡ Extreme μ, but also extreme internal resistance
- ➡ ”Current trickler”, only useful for few very special applications

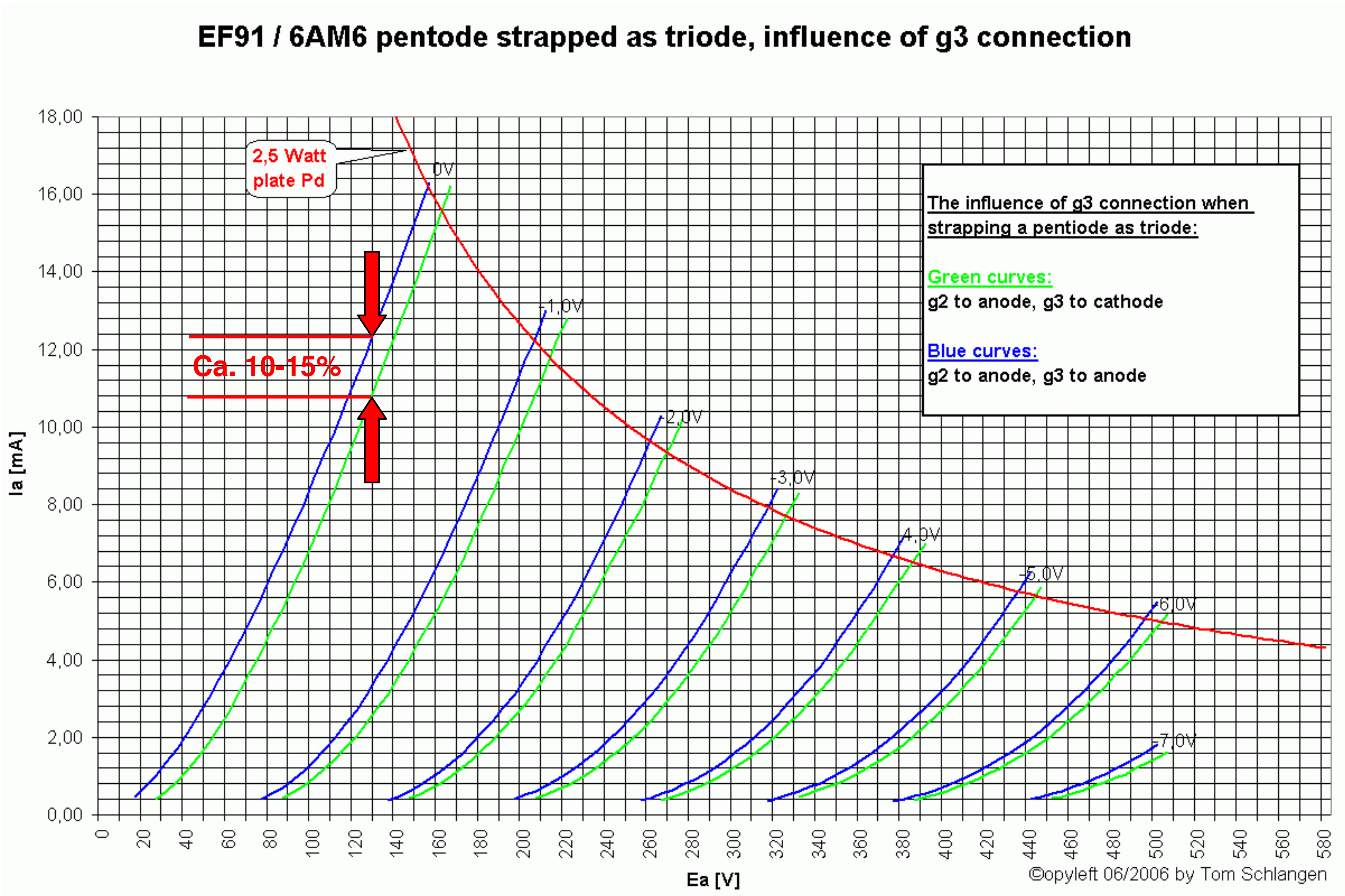


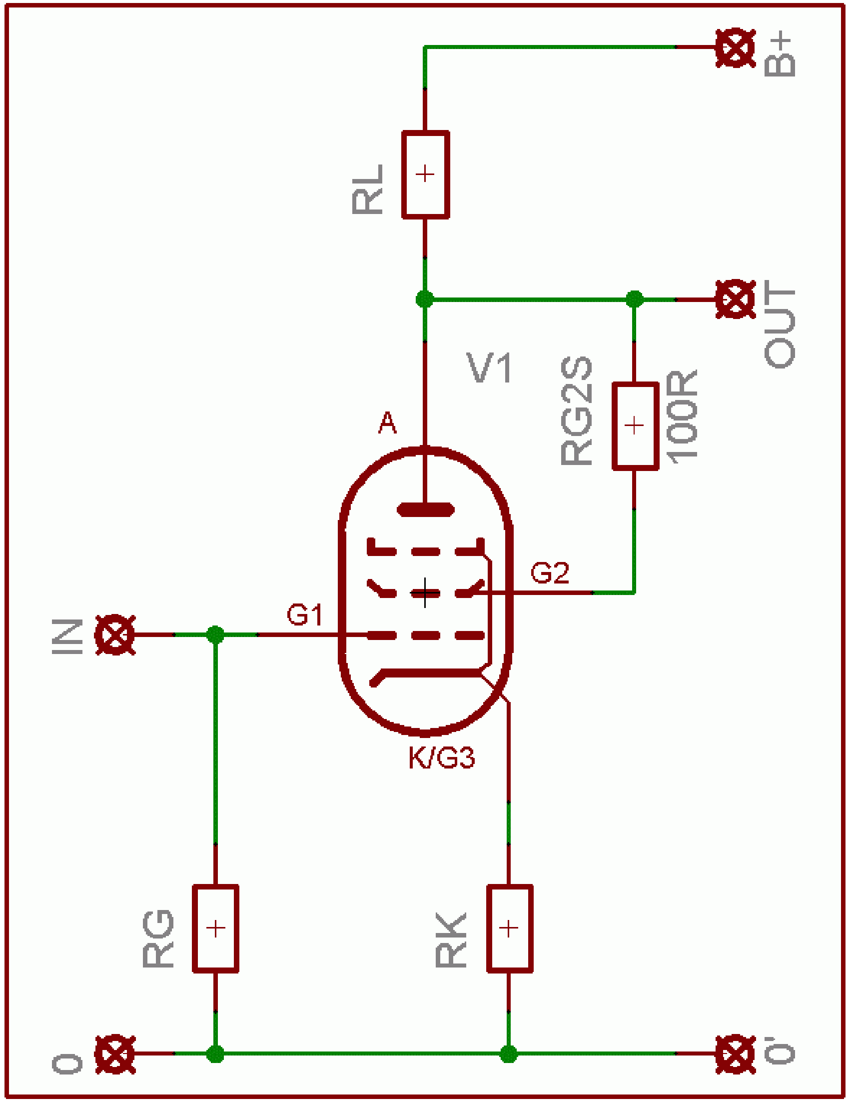
Possible suppressor grid connections

Suppressor grid and screen grid connected to anode

- Screen and suppressor grids swing with anode
- ➡ Normal functions of g2 and g3 are disabled
- ➡ Screen and suppressor grid area effectively added to anode area
- ➡ Alternate viable method to connect the suppressor grid (if it is accessible)

Comparing suppressor grid connection influence





Summary:

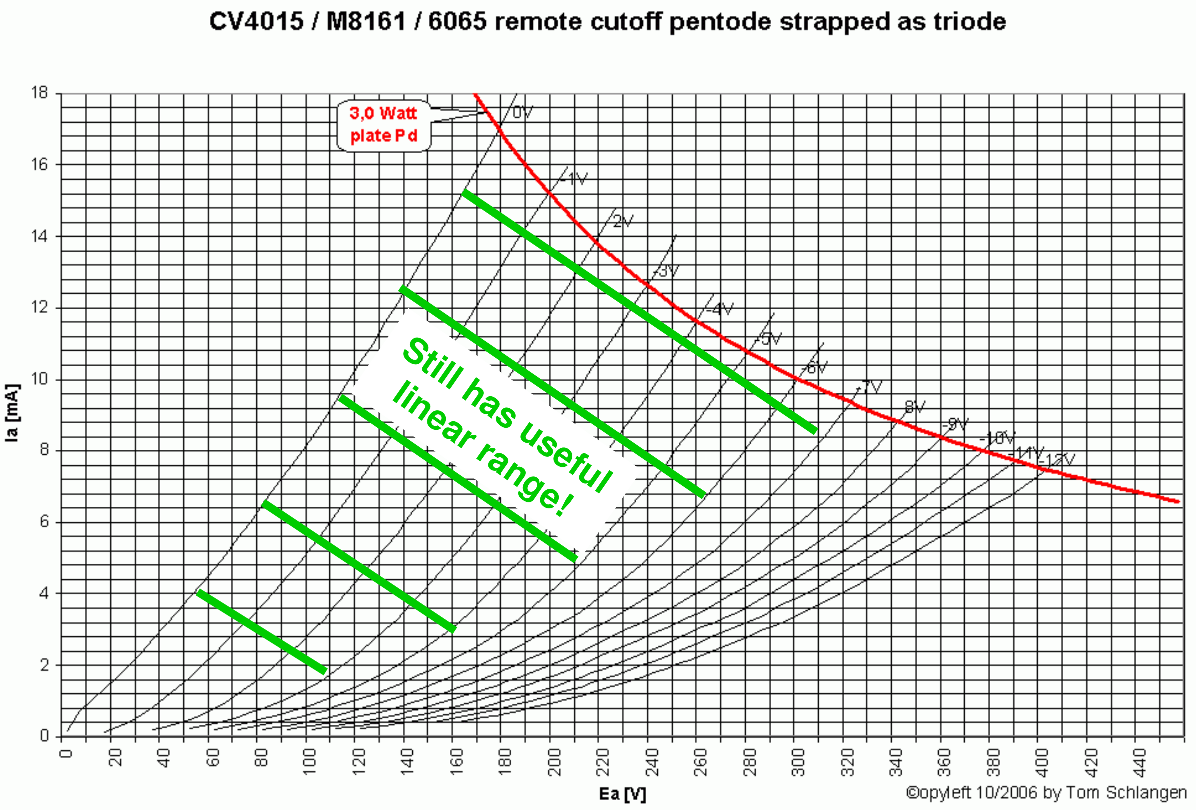
Preferred grid connections to get triode characteristics from a pentode are:

- Screen grid to anode
- Suppressor grid to cathode (or anode)

Preferred method to connect g2+g3!

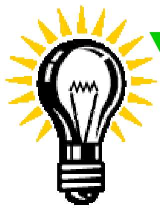
What happens when you triode-strap a remote cutoff (variable µ/gm) pentode like EF92/6CQ6?

You get a variable µ/gm triode, of course ☺



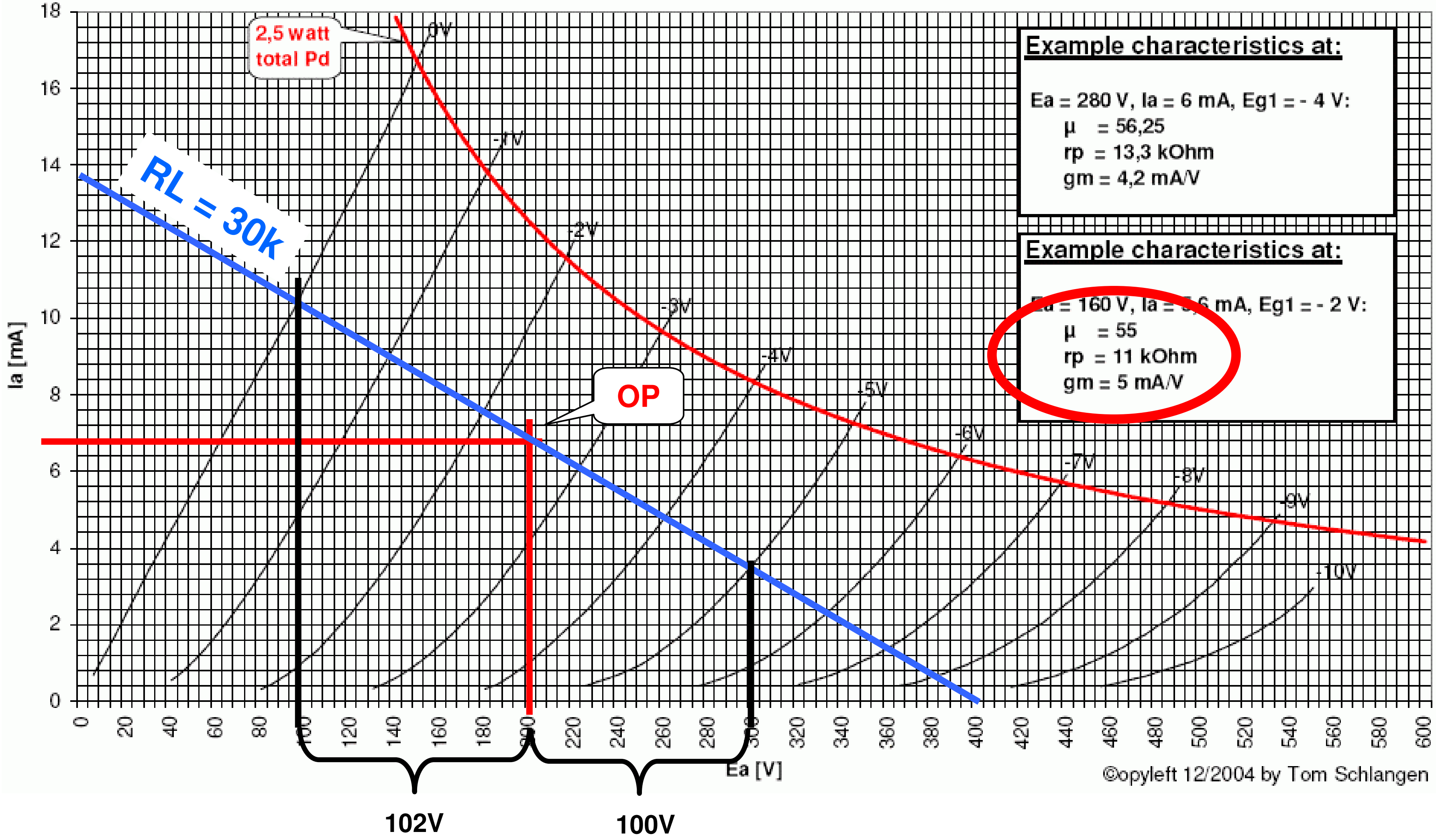
Some practical examples

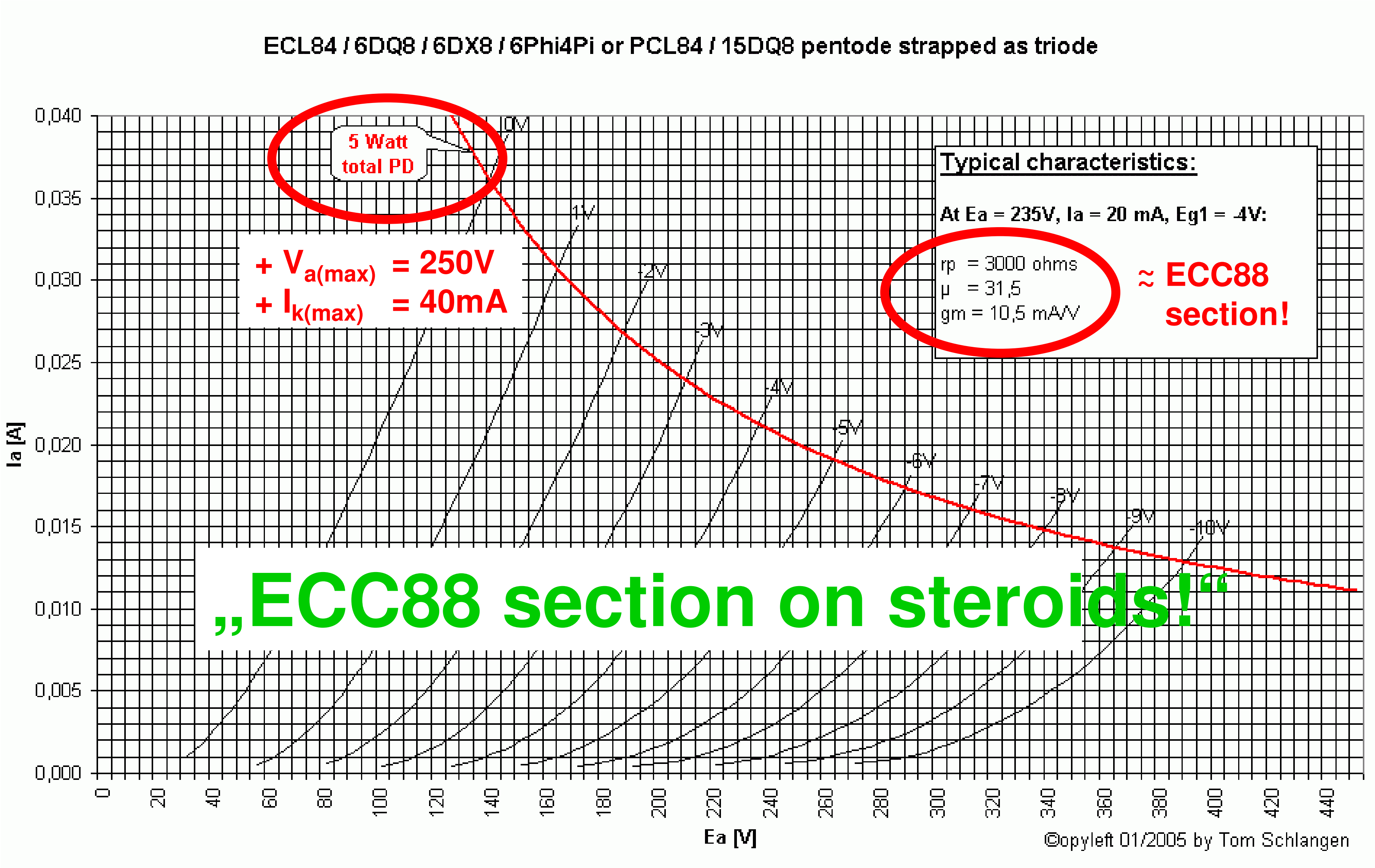
- Sometimes manufacturers of pentodes also published triode connected curves and often they are used this way. Famous examples include: EF86 (extremely linear), EL34 (everybody knows it can power a decent triode SE or PP amp).
- But – are there “sleeper tubes”? Cheap pentodes nobody uses in triode connection because there are no anode curves available for them? Maybe even from (gasp!) TV set heritage? And, can they compete to real triodes?



Yes, yes and yes!

EF184 / 6EJ7 frame grid pentode strapped as triode




ECL84 / 6DQ8 / 6DX8 / 6Phi4Pi or PCL84 / 15DQ8 pentode strapped as triode
5 Watt total PD
+ $V_{a(max)}$ = 250V
+ $I_{k(max)}$ = 40mA
Typical characteristics:
At Ea = 235V, Ia = 20 mA, Eg1 = -4V:
rp = 3000 ohms
µ = 31,5
gm = 10,5 mA/V
≈ ECC88 section!
„ECC88 section on steroids!“
0V
-1V
-2V
-3V
-4V
-5V
-6V
-7V
-8V
-9V
-10V
Ia [A]
Ea [V]
0,040
0,035
0,030
0,025
0,020
0,015
0,010
0,005
0,000
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440
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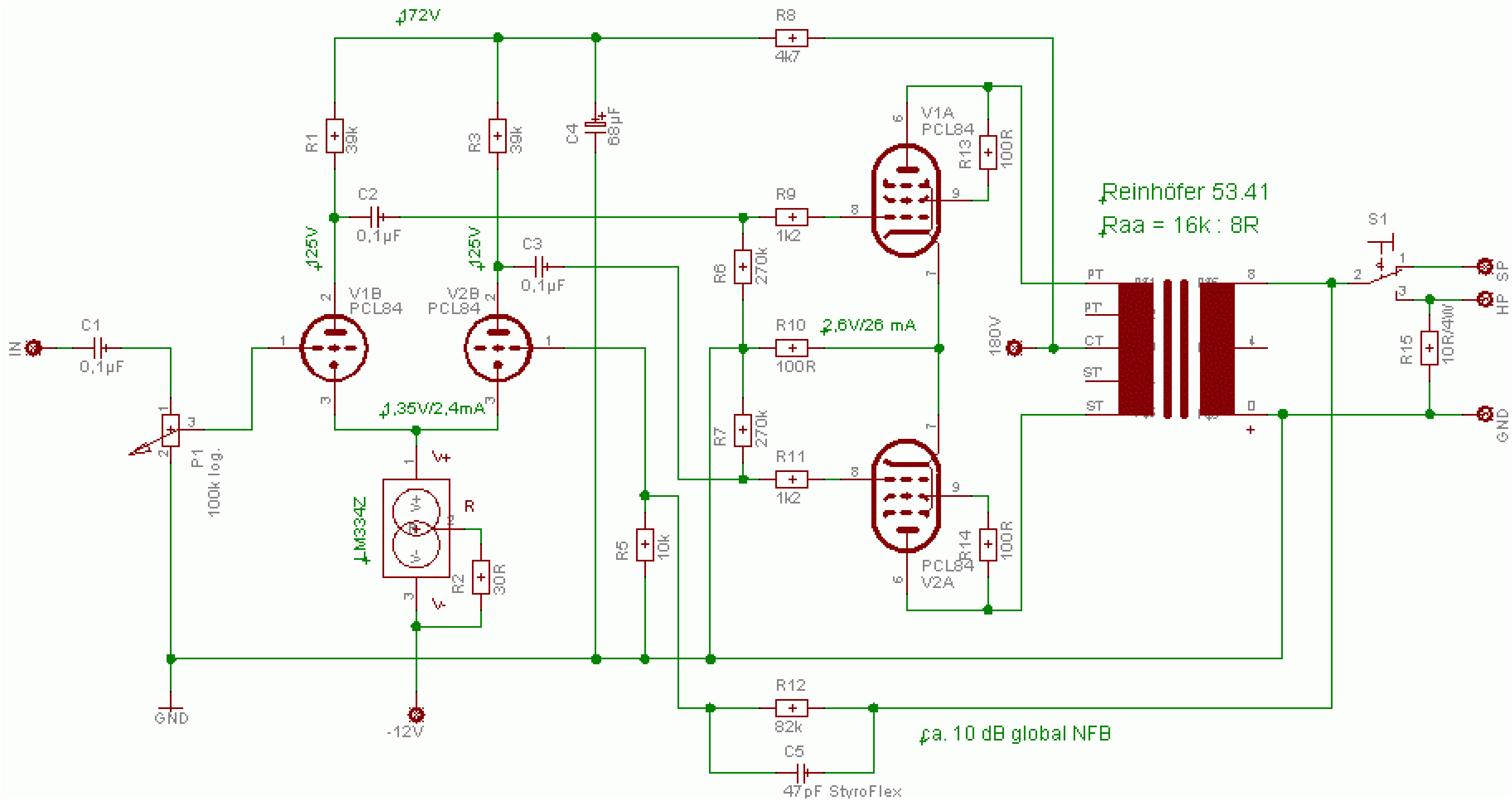
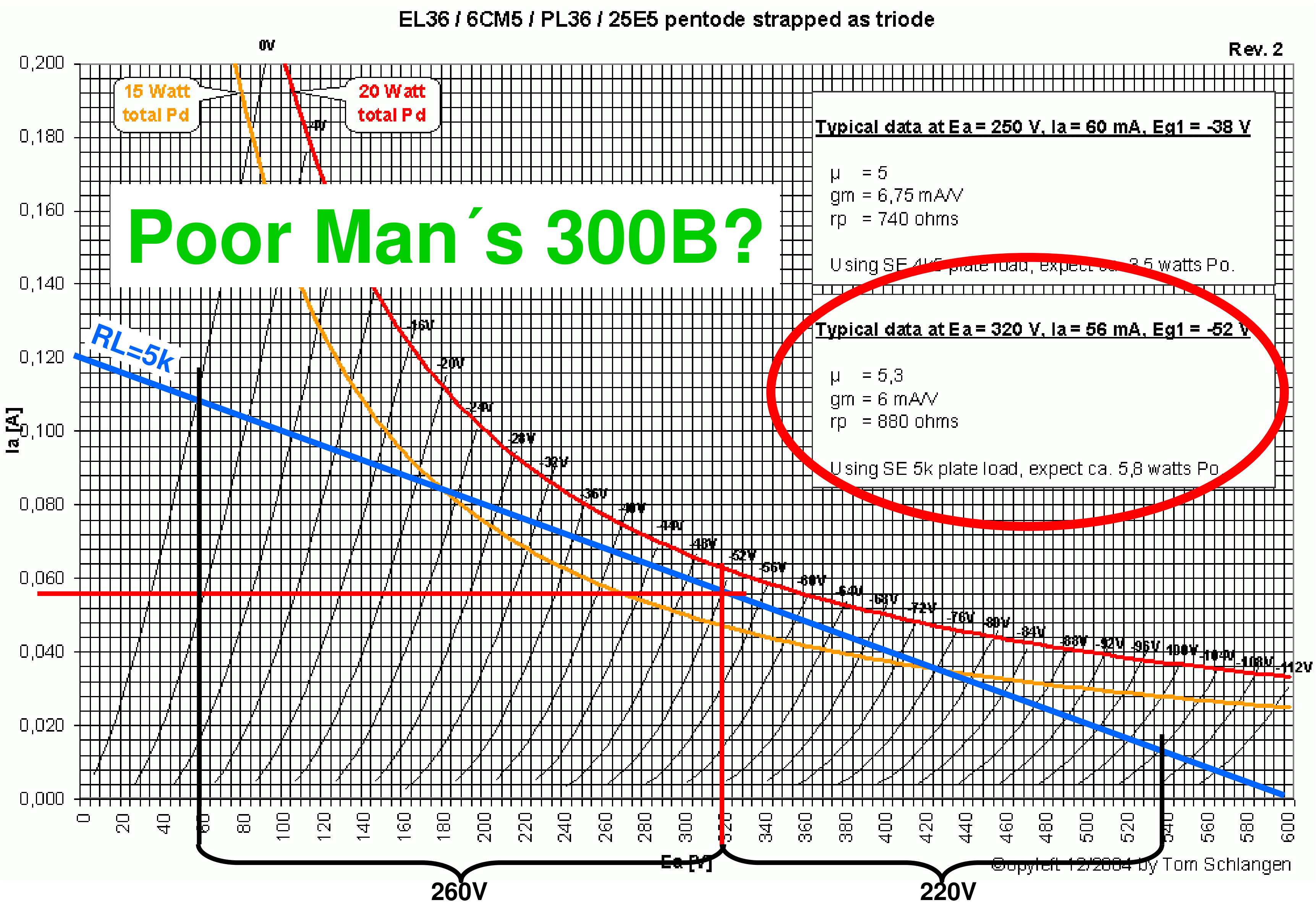
Example: PCL84 compound valve based headphone amp

- Pentode sections connected as triodes in push-pull operation
- 100% class A triode(d) push-pull operation
- About 1W/channel Po into 8 Ohms
- Due to internal dummy load, it can drive headphones from <32 Ohms up to whatever impedance
- Also can drive small bookshelfs
- Automatic disconnect of speakers on headphone plug insertion

Example: PCL84 TV compound valve based headphone amp




EL36 / 6CM5 / PL36 / 25E5 pentode strapped as triode
Rev. 2
15 Watt total Pd
20 Watt total Pd
Poor Man´s 300B?
RL=5k
Typical data at Ea = 250 V, Ia = 60 mA, Eg1 = -38 V
μ = 5
gm = 6,75 mA/V
rp = 740 ohms
Typical data at Ea = 320 V, Ia = 56 mA, Eg1 = -52 V
μ = 5,3
gm = 6 mA/V
rp = 880 ohms
Using SE 5k plate load, expect ca. 5,8 watts Po.
Ia [A]
Ea [V]
260V
220V
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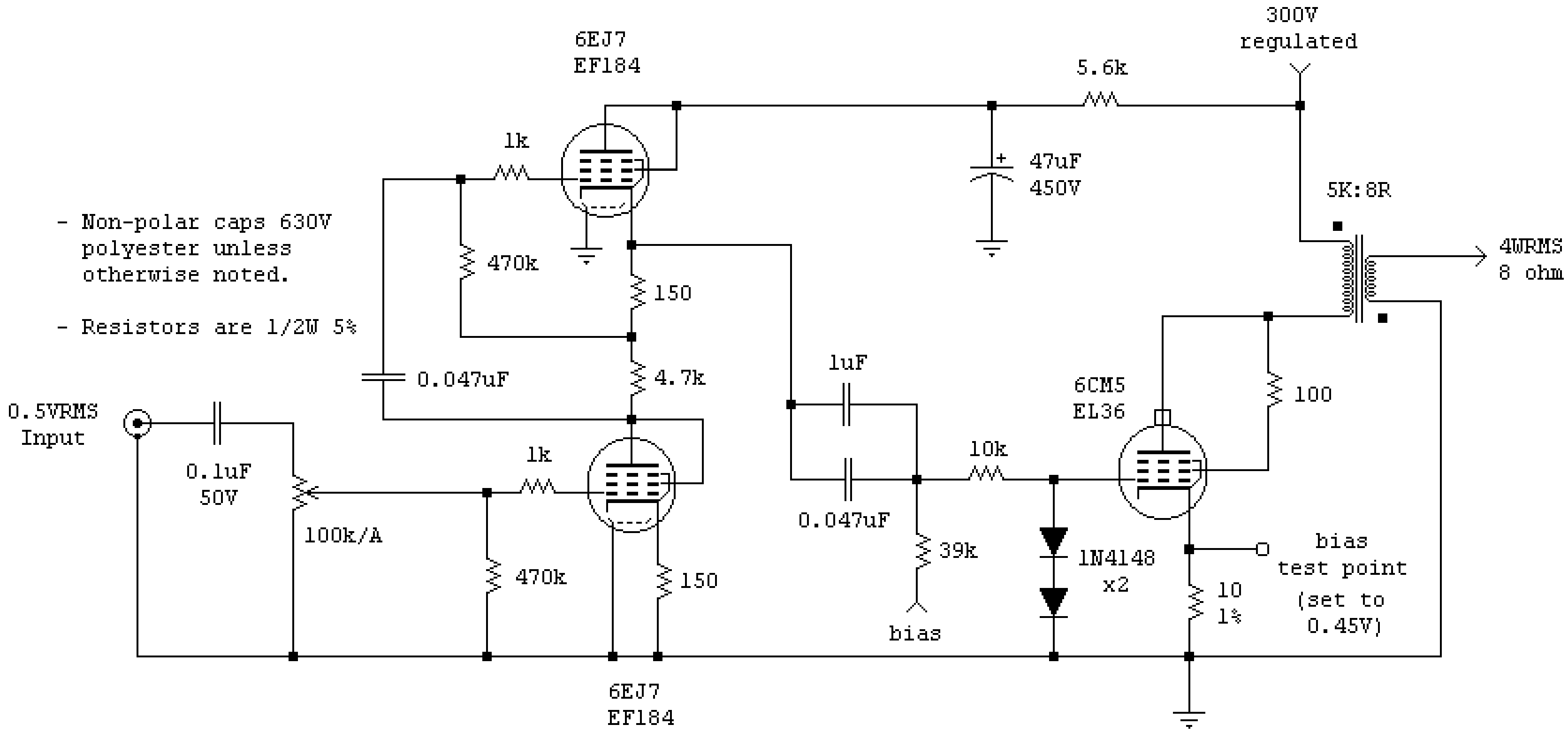
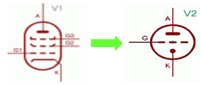
Example: SE amp circuit using “TV duty” valves

➔Trioded EF184 used as µ-follower driver

➔Trioded EL36 used as SE power stage



Circuit courtesy of Gregg van der Sluys



Thank you very much for your attention!

<u>Next lecture:</u>

Mr. Morgan Jones

14:00, library room