Pentodes connected as Triodes

by Tom Schlangen
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
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Pentodes connected as Triodes

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 $\mu$, 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.

- $C_{a-g}$ is a path transferring energy back from the anode (output) to the control grid (input), thus reducing efficiency. This effect is mostly dependent on $C_{a-g}$ 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 $C_{a-g}$ massively.

- It also can be used as an additional control grid.

- An electron tube with four electrodes is called tetrode.
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Tetrode characteristics – fixed screen voltage

Usable area with $V_a > V_{g2}$

$V_{g2} = 500\,\text{V}$
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

$V_a < V_{g2}$

$V_a > V_{g2}$

Reduced kink area

Enlarged operation area

$V_{g2} = 250V$
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”.
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Where to connect what?

.... to get triode characteristics, again!
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)

\[ V_{g2} = 250 \text{V}: \text{Wide usable range} \]

\[ V_{g2} = 0 \text{V}: \text{hardly useful!} \]
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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
Pentodes connected as Triodes

**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

- Common misconceptions:
  - The purpose of this resistor is *not* to limit screen current (it hardly does, except when blowing like a fuse)
  - The purpose of this resistor is *not* to keep $V_{g2}$ below $V_a$ (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 $g_1 + g_2 + g_3$ control action is of multiplicative character
- Extreme $\mu$, but also extreme internal resistance
- "Current trickler", only useful for few very special applications
Pentodes connected as Triodes

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

EF91 / 6AM6 pentode strappd as triode, influence of g3 connection

The influence of g3 connection when strapping a pentode as triode:

- **Green curves:** g2 to anode, g3 to cathode
- **Blue curves:** g2 to anode, g3 to anode

Ca. 10-15%
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!
Pentodes connected as Triodes

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

You get a variable $\mu/gm$ triode, of course 😊

Still has useful linear range!
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

Example characteristics at:
- $E_a = 280 \text{ V}$, $I_a = 6 \text{ mA}$, $E_g = -4 \text{ V}$:
  - $\mu = 56,25$
  - $r_p = 13,3 \text{ kOhm}$
  - $g_m = 4,2 \text{ mA/V}$

Example characteristics at:
- $E_a = 160 \text{ V}$, $I_a = 5,6 \text{ mA}$, $E_g = -2 \text{ V}$:
  - $\mu = 55$
  - $r_p = 11 \text{ kOhm}$
  - $g_m = 5 \text{ mA/V}$

- $RL = 30k$
- $2,5 \text{ watt total Pd}$
- $102V$
- $100V$
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ECC88 section on steroids!

\[ + V_{a(\text{max})} = 250V \]

\[ + I_{k(\text{max})} = 40mA \]
**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 bookshelves
- Automatic disconnect of speakers on headphone plug insertion
Example: PCL84 TV compound valve based headphone amp
Poor Man’s 300B?

EL36 / 6CM5 / PL36 / 25E5 pentode strapped as triode

Typical data at $E_a = 260\, \text{V}$, $I_a = 60\, \text{mA}$, $E_{g1} = -38\, \text{V}$
- $\mu = 5$
- $g_m = 6.75\, \text{mAV}$
- $r_p = 740\, \text{ohms}$

Using SE 36 plate load, expect ca. 15 watts $P_o$.

Typical data at $E_a = 320\, \text{V}$, $I_a = 56\, \text{mA}$, $E_{g1} = -62\, \text{V}$
- $\mu = 5.3$
- $g_m = 5\, \text{mAV}$
- $r_p = 880\, \text{ohms}$

Using SE 5k plate load, expect ca. 5.8 watts $P_o$. 
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!

Next lecture:
Mr. Morgan Jones
14:00, library room