10.5.1 Single-ended (class A)-operation, tetrode, pentode

In the single-ended, class-A power-stage, one (single) power-tube operates in common-cathode configuration with the output transformer being part of the plate circuit (transformer-coupling). Without AC-drive ("quiescent state"), a stable balance appears – it is called the operating point (**OPP**). The characteristics shown in **Fig. 10.5.2** yield an OPP at 250 V and 48 mA, if a voltage of -7.5 V between (control) grid (g_1) and cathode is chosen. This can be done e.g. by using a cathode-resistor of 142 Ω. The cathode-current (the sum of the 48-mA-plate-current and the 5-mA-screen-grid-current) will then generate a positive cathode-voltage of + 7.5 V (relative to ground). With the control-grid at ground-potential (U_{g1} = 0) a control-grid-to-cathode-voltage of -7.5 V results (i.e. the control grid is negative vs. the cathode).

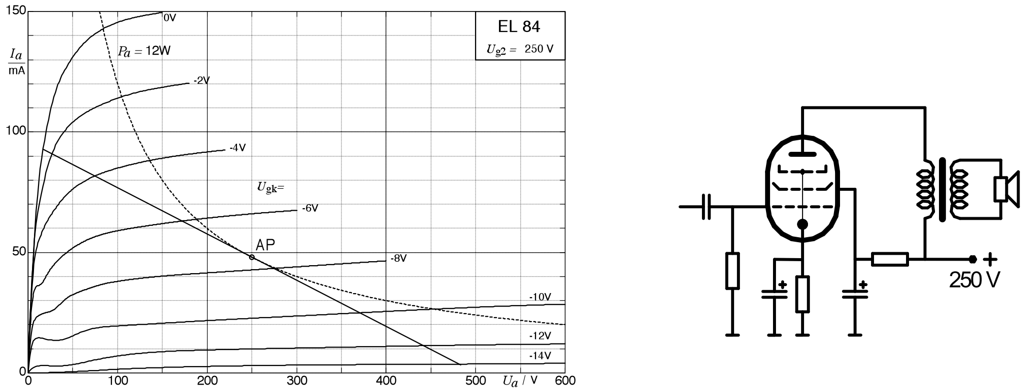

Fig. 10.5.2: Output characteristics of the EL84, power-stage circuit (single-ended class-A operation). AP = OPP

As a drive signal appears ($U_{g1} \neq 0$), plate-voltage and –current change. As a first approach, it will be sufficient to consider the transformer in the plate-circuit as a large inductance connected in parallel with an ohmic resistor (Chapter 10.6). In this model we have only pure DC flowing through the inductance, and only pure AC flowing through the resistor. With a drive-signal present, the U_a/I_a-point will move along the **load-line** given in Fig. 10.5.2: as the grid-voltage is enlarged, the plate-current increases and the plate-voltage drops until a limit is reached at 17 V / 92 mA with U_{gk} = 0. **Fig. 10.5.3** shows that the relation between input- and output-magnitudes is non-linear: merely with small drive-signals around the operating point we can obtain an approximate image of the input signal with small harmonic distortion. In addition, we need to bear in mind that in reality, the power-tube is rarely driven via a low-impedance source. Often, the driver-tube ahead of the power-tube is operating in common-cathode configuration i.e. with a relatively high internal impedance (e.g. 50 kΩ) – in this case the grid-current of the power-tube already distorts the control (drive) signal.

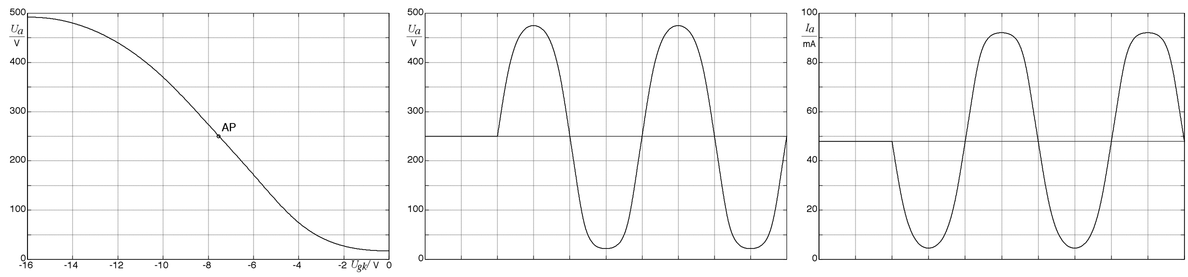

Fig. 10.5.3: Transmission characteristic; plate-voltage and plate-current for sinusoidal U_{gk} (from a stiff voltage source).

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The output transformer takes the AC-component from the plate-circuit and generates the loudspeaker-current that is enlarged by the turns-ratio factor *TR* (secondary current, Chapter 10.6). The AC-load of the power-tube results from the inclination of the load line; in Fig. 10.5.2 this is 5208 Ω (19.2 mA / 100 V). From this load-impedance at the plate, and from the loudspeaker impedance (e.g. 8 Ω), we get a first approximation of the transformation ratio (ratio of turns in the two transformer windings) *TR* of the transformer: $TR = \sqrt{5208 / 8} = 25.5$. In view of the transformer losses, this value should be decreased by about 10 % – now we arrive at approximately $TR \approx 23$ [for more exact calculations see e.g. Schröder, Vol. II].

In quiescent state (i.e. without any drive signal), the plate is at 250 V and the plate-current is 48 mA. Multiplying these two values gives us the dissipation loss at the plate of P_a = 12 W. Since the (idealized) load-impedance was assumed to be an R/L parallel-circuit (= short-circuit for DC), the supply voltage is calculated as U_B = plate-voltage + cathode-voltage = 257.5 V. This is a bit too much "lab jargon" and we need to get more precise. What the data books term "plate-voltage" is in fact the voltage drop U_{ak} between plate and cathode; it is also called plate/cathode-voltage. In a series connection to it we have the voltage drop occurring across the cathode resistor, also termed cathode-voltage: $U_B = U_k + U_{ak}$. Without drive signal, the cathode resistor (142 Ω) absorbs 0,4 W while the plate absorbs 12 W, and the screen grid 250 V · 5 mA = 1.25 W. Consequently, the power supply needs to deliver, in **quiescent state**, 13.65 W. **With a drive signal**, the plate-current becomes time-variant und oscillates between two limit-values, e.g. 5 und 92 mA (Fig. 10.5.3). If we ignore the non-linear re-shaping, the average of the current remains constant, which implies: the power that the power supply needs to make available is approximately constant i.e. independent of the drive signal level! Multiplying the AC-components of the plate-voltage and the plate-current (Fig. 10.5.3) results in the **effective power** pushed into the load-impedance: P_N = 6 W. Given an ideal transformer, this power fully arrives at the load-impedance (the loudspeaker); in reality a loss of 20% is likely. Only about 4.8 W arrive at the loudspeaker and the remaining 1.2 W are converted into heat in the transformer.

In summary: the power supply needs to deliver about 14 W independently of the drive signal, which leaves just under 5 W output power at full drive level – with the output signal being already subjected to substantial non-linear distortion (strong THD). The efficiency of this circuit is 35%, at best – or even as low as 26% if we include in our considerations the tube heating. The latter is necessary to operate the EL84, and gobbles up another 4.8 W.

As inefficient this circuit may be – it was indeed used in some early guitar amplifiers. One of the first VOX-amplifiers, the AC-4, generated 4 W from a single EL84 in a single-ended class-A configuration. The first smaller Fender amps uses the single-ended Class-A circuit, as well – we find it e.g. in the Champ, Bronco, Princeton and Harvard amps, although these used the 6V6-GT, a 12W beam-power tetrode rather than the EL84. Over the years, the Fender amps in particular were subject to various modifications. Among these the increase in **supply voltage** is especially striking: early versions had 305 V; an increase to 305 V followed, and finally there was as much as 420 V. Can we boost the output power that way? Which is the optimum operation point to achieve the maximum power output? Which load impedance is optimal for the tube? Using simplifications in the tube- and transformer-data, the calculation for optimum working conditions is unproblematic. However, in the real world one needs to consider deviations from these ideal conditions. In particular the maximum current-load of the power tubes is subject to manufacturing tolerances, and transformer losses (build-size!) determine the eventually achievable output power, too.

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With the idealized assumption that, in the plate-circuit of the power tube, the power-hyperbola is the only limitation, the left section of **Fig. 10.5.4** shows two load-lines that each are tangents to the hyperbola. The division U_{AP} / I_{AP} yields the optimum operating point (OPP), corresponding at the same time to the negative slope of the hyperbola at the OPP. The maximum possible voltage deflection at OPP_1 is 400 V_{ss}, resulting in 6 W, with a load resistance of 3333 Ω. The same power can be achieved in OPP_2: the voltage deflection is indeed larger at 600 V_{ss}, but the current is correspondingly smaller. If we define the power hyperbola as limit, the achievable maximum power is always exactly half of the maximum dissipation-power at the plate – independent of the OPP. For a **real circuit** we need to factor in that the plate-current cannot become indefinitely large. In the right-hand section of the figure, the output characteristic of a 6V6-GT is indicated as limit for the case that the grid/cathode-voltage is zero. This curve must not be seen as the absolute limit – even larger plate-currents would be possible if the grid/cathode-voltage were positive. However, the typically used drive-circuits could not deliver the necessary current, and consequently it is purposeful to define, in addition to the power hyperbola, $U_{gk} = 0$ as the limiting factor. Now, the maximum voltage deflection reachable at OPP_1 is not 400 V_{ss} anymore but decreases to 334 V_{ss}, and the OPP is not located in the middle of the load line any longer. A conducive shift of OPP_1 from 200 V to 233 V does enable us to establish symmetry with regard to the maximum drive level. However, the reduction of the maximum voltage deflection by 16.5% decreases the maximum power-offering by 30% (in our example from 6 W to 4.2 W). For OPP_2, the reduction of the voltage-deflection makes itself less strongly felt (5.6 W instead of 6 W), and we can expect the operation with a higher voltage to bring somewhat **more power**.

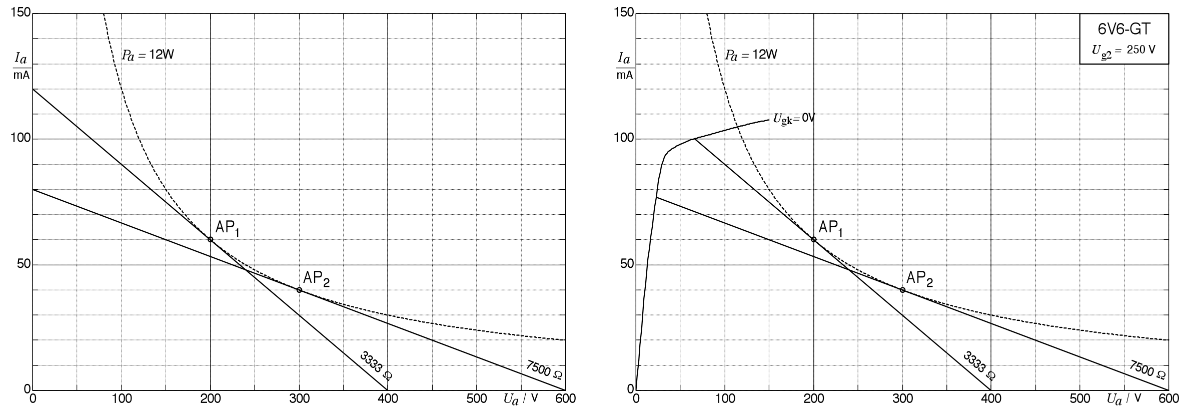

Fig. 10.5.4: Output characteristic with two different operating points; the power hyperbola is the limit.

The above calculations regarding the achievable power-output deliberately are of a rather "principle" character in order to illustrate basic functions within the power stage. If we do not consider the power hyperbola as limiting factor, the circuit will deliver 50% of the maximum power dissipated at the plate to the output transformer – irrespective of the tube used. This upper power-threshold can only become smaller (and never bigger) as individual tube-limit-data are incorporated. Besides the maximum power-dissipation at the plate, in particular the maximum tolerable plate-voltage and the maximum allowable power-dissipation of the screen grid need to be considered. For a supply voltage of 300 V, up to 600 V may occur at the plate, and even as much as 840 V for 420 V supply voltage. Also, even higher voltages may appear, since the load impedance (loudspeaker) is not a purely ohmic 8-Ω-resistor but will become inductive (and thus larger) at high frequencies. Even if the insulation within the transformer is exemplarily well done: at too large voltages, arc-over is possible in or at the tube, and it can lead to destruction.

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So much for an introductory, basic description of the behavior of a single-ended power-stage – now on to the details. For the **triodes** deployed in preamplifiers, a simple power law was formulated as an approximation (Child/Langmuir, Chapter 10.1.3):

$$I_a = K_2 \cdot (U_{gk} + U_a/\mu)^{3/2} = K_2 \cdot U_{St}^{\ 3/2} \qquad \text{Triode characteristics}$$

The plate-current I_a depends on the grid/cathode-voltage U_{gk}, on the plate-voltage U_a, and on the open-loop gain μ, the latter also known as **durchgriff**: $D = 1/\mu$. To get even more into detail: the free conducting electrons in the metal cathode are highly mobile but cannot leave the metal in its cold state. A special coating combined with red-heating enables a significant portion of the electrons to leave the metal and form, in the immediate vicinity around the (heated) cathode, a kind of "electron-mist" – also called "space-charge cloud". The more electrons accumulate in front of the cathode, the more negative this **space-charge area** becomes, and the more effectively further electrons are inhibited to move against this negative potential – an equilibrium results. A positively charged plate will superimpose an electron-accelerating plate-field over the electron-inhibiting space-charge field, and the former field will suck electrons away from the cathode and draw them to the plate. The space-charge decreases, enabling more electrons to leave the cathode. The electrons leaving the cathode form the cathode-current, and the electrons arriving at the plate form the plate-current. A **(control-) grid** (three-electrode-tube = triode) introduced between cathode and plate will create, via its electrical potential, an additional field. Consequently, on top of the space-charge field, *two* fields that are controllable via the electrodes act on the electrons and therefore influence the current: one generated by the (control-) grid, and the other generated by the plate. Since the grid is positioned closer to the cathode, it exerts the bigger influence: the plate needs to first "reach through the control grid to the space-charge" – hence the term "durchgriff" (the term taken from German, meaning "reaching through"). For the ECC83, the datasheet indicates a rather small value at $D = 0.01$. However, with the plate-voltage being about 100 times the value of the grid/cathode voltage, both U_a and U_{gk} influence the plate-current. Textbooks on practical circuit-design see the grid as control-electrode and designate U_{gk} as control-voltage. More theoretically oriented oeuvres combine the summands $U_{gk} + D \cdot U_a$, using the same term **control-voltage** for the combination i.e. this term may have two different meanings! In the formula above, U_{St} is the theoretical control-voltage considering both the influence of grid *and* plate, with K_2 being a tube-specific constant.

One may consider it a problem that the plate-current of the triode does not only depend on the grid/cathode-voltage but also on the plate-voltage. A solution can be found by inserting an additional **screen grid** (g_2) between control grid (g_1) and plate, and connecting it to a high positive voltage – this way the electrons are predominantly accelerated by the control grid and the screen grid, with the plate-potential retaining merely a minor significance. For the resulting 4-electrode tube (= **tetrode**), the potentials of all electrodes can be described via a theoretical control-voltage:

$$U_{St} = U_{g1} + D_1 \cdot U_{g2} + D_1 \cdot D_2 \cdot U_a \qquad \text{Control-voltage of the tetrode}$$

The tube parameters D_1 and D_2 – both considerably smaller than 1 – can again be interpreted as durchgriff. $D_1 \cdot D_2$ shows the (intended) small influence of the plate-voltage.

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As an example: if the control-grid-voltage has to change by 1 V in order to change the plate-current by 10 mA, then for the same plate-current change the screen-grid-voltage would have to be changed by 20 V, or the plate-voltage by 400 V. To map the control-voltage onto the plate-current, we could use the power law for the tetrode, as well, but we would need to introduce considerable **corrections** to obtain a good match to the actual behavior. A main reason for this discrepancy between simple theory and practice is the release of **secondary electrons** from the sheet-metal of the plate. As soon as the electrons arriving from the cathode are accelerated with more than 10 V difference in potential, they have enough energy to knock, as they hit the metal, further electrons from the plate – these are the secondary electrons. With the screen-grid-potential lower than the plate-potential, this process is not disruptive because the secondary electrons return to the plate. However, for higher screen-grid-potential the secondary electrons fly on to the screen grid – correspondingly decreasing the plate-current and increasing the screen-grid-current. This is the reason why an enormous bump appears in the I_a/U_a-characteristic of the tetrode for small plate-currents. This bump is undesirable (**Fig. 10.5.5**).

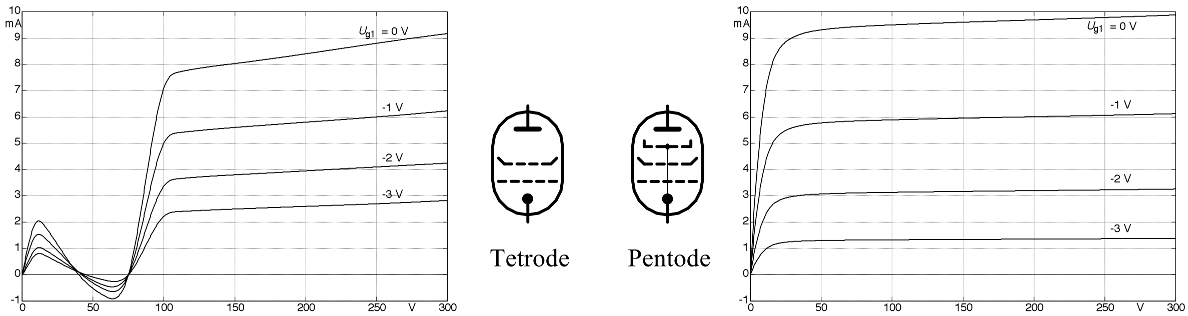

Fig. 10.5.5: Output characteristics (I_a vs. U_a) of a tetrode (left) and a pentode (right).

Corrective action is provided by yet another electrode, the **suppressor grid** (or retarding grid) located between screen grid and plate. Its job is to push back the secondary electrons en route from the plate so that they will not land on the screen grid. This only works if the suppressor-grid potential is much lower than the screen-grid potential, and therefore the suppressor grid is normally connected to ground. The fast electrodes emitted by the cathode are pretty much unaffected by the this suppressor grid while the slow secondary electrons knocked out of the plate are not able to overcome the potential difference to the suppressor grid and return to the plate. Staff at Philips developed the first commercial version of this five-electrode tube (= **pentode**), with a corresponding patent filed in 1926. For a short time, pentodes are also found in pre-amplification stages of guitar amplifiers but these were soon replaced by triodes (Chapter 10.1). In contrast, we find almost exclusively power-pentodes in the power-stages, for example the EL84 (e.g. VOX), or the more powerful EL34 (e.g. Marshall).

The London-based tube manufacturer **MO-V** (MO-Valve or Marconi-Osram Valve Co Ltd.) was not allowed to manufacture pentodes due to the patent owned by Philips, and developed (around 1933) a serious alternative to the pentode: the **Beam-Power-Tetrode**. Its baffles concentrate the electron-stream such that strong space-charges strongly deemphasize the characteristic tetrode-bump. It appears, however, that there was not that much confidence in the concept at MO-V, and the corresponding rights were sold to **RCA** in the United States. RCA used them to very successfully develop the beam-power-tetrode **6L6**, and this again forced MO-V to act all the more. They introduced the **KT-66**, the "**k**ink-less **t**etrode". Both the 6L6 and the KT-66 were manufactured in many variants that can differ substantially.

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The power tubes employed in guitar amplifiers may be divided into three main groups: pentodes, British beam-tetrodes and US beam-tetrodes. Among the **pentodes**, there is the EL84 for low-power applications, and the EL34 for high power. The KT-66 and the more powerful KT-88 are the **British beam-tetrodes**. Their **American counterparts** are the smaller 6V6 and the larger 6L6. All these tubes have undergone multiple redesigns since their introduction to the market; that is why we cannot speak of "the" 6L6. First came the development step from steel- to glass-container, then there were changes in the shape of the container, but also in the electrodes and thus in the electrical parameters. The RCA 6L6-GB is rated with a maximum plate-dissipation of **19 W**, the Tungsol 6L6-GB is rated at **22 W**. Can the Tungsol-tube therefore carry a higher load? That is difficult to say, because we read in the RCA datasheet: *Design-Center Values*, but in the information by Tungsol: *Design Maximum System* (more about these rating systems in Chapter 10.5.9). The Sylvania 6L6-WGA is specified at **19 W** (*Design Center*), but also at **21 W** (*Absolute Maximum*). As a first approximation, these are all tubes that are the result of a development from the 6L6, via the 6L6-G and the 6L6-GA, to the 6L6-GB, that related predominantly to the shape. Only for the **6L6-GC** we see a pronounced power upgrade to a plate dissipation of **30 W** (*Design Maximum Values*); this is probably based on changes in the metal sheet of the plate. None of these tubes were developed specifically for guitar amplifiers – that market was much too small at the time. Rather, we read: *For Radio Receivers*. There were also particularly robust *military tubes* designated with a supplementary W, e.g. the **6L6-WGB**. The corresponding electrode-build was optimized to withstand the stringent MIL-testing.

The **KT-66** is the British counterpart to the 6L6. It is specified with a maximum plate dissipation of 25 W in the Osram data-sheet; we find the same data in the Marconi data-sheet, and checking the info from MO-V yields 25 W (Design Max) or 30 W (absolute Max), respectively. **MO-V** is the moniker for the Marconi-Osram-Valve-Company, that offered the KT-66 globally under the **GEC** label. This is GEC = General Electric Corporation of England, not to be confused with General Electric USA. Both the 6L6 and the KT-66 are beam-tetrodes, i.e. tubes without a suppressor grid. Because the beam-forming sheets can be seen as a fifth electrode, after all, these tubes are often labeled as pentodes, too (despite the lack of an actual suppressor grid). The **EL34**, however, is a *true* pentode, specified at 25 W – or at 27.5 W ("at maximum drive level"). All these tubes show similar data regarding the maximum load, but we may not conclude that they can be arbitrarily interchanged – their control characteristics show considerable differences, after all.

Before we delve more deeply into the area of tube characteristics, let us take a short look at other power-tubes. Around 1950, Tung-Sol develops the **5881** and advertises it as an advancement of the 6L6 (or the 6L6-GA). In 1962, the maximum plate dissipation of the 5881 is still specified at 23 W (Design Center System) – but by that time, the 6L6 has enjoyed the further development into the 6L6-GC (30 W), and the 6L6-WGB (26 W) has been available at least since 1955. It is not surprising that not everybody regards the 5881 as the "better 6L6". And then: what does "better" mean in this context? Is this from the point-of-view of the MIG-pilot demanding full function even after a rough touchdown? Or from the point-of-view of the aficionado of classical music expecting the least possible distortion? Or from the point-of-view of the Jazz guitarist having just discovered that the tone control does not *have* to be stuck at "0" all the time? Or from the point-of-view of the Eddie-epigone overdriving his equipment (his "rig") exactly "VH-like"? To state "*the 5881 is the better 6L6*" is just as misguided as "*6L6 = KT66 = 5881*". "The" 6L6 does not exist, just as "the" KT66 or "the" 5881 do not exist. It is not just that the datasheets indicate differences – today many a KT66 internally is but a 6L6-variant.

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When evaluating tubes in general, and power tubes in particular, two criteria offer themselves: the **sound**, and the operational lifespan. Sure, price and availability also figure – but we will tackle that later. The lifespan may be five hours or five years; it has its own chapter dedicated to it (Chapter 10.5.9). The sound is advertised with “powerful bass” or “clear treble”, and consequently many guitarists presume that tubes would feature a frequency-dependent transmission characteristic – like that found in a loudspeaker. However, this assumption is not correct as such: tubes can process frequencies as low as desired♣, and frequencies as high as they come; whether the upper cutoff-frequency is found to be 100 MHz or 200 MHz is immaterial in the present context. On the other hand, to deduce that all tubes would sound the same is incorrect as well. It’s not that the tube itself would have a “sound”, but it does influence the transmission behavior of the power stage as a whole. It does make a difference to the loudspeaker whether it is driven by a source of high or low impedance, and the character of the distortion is tube-specific, as well. The generally publicized view seems to be: tubes will sound somehow, expensive tubes will sound better, and old tubes will sound best.

Cheapest are so-called *industrial tubes* i.e. tubes manufactured for industry. Well – of course it’s not only industry that gets them, because how else would they be offered in minimal quantities to musicians. “Industrial tube” probably is supposed to indicate that the musician will receive these tubes in the same condition that industry would receive them: without additional value added by the retailer. Without added value does not mean without an add-on to the price tag, though – that a business makes money from this commodity, too, is the legitimate result of mercantile aspiration. Besides industrial tubes, there are *selected/matched* power tubes. They carry mysterious numbers on their sockets and/or on their carton, and they were “paired”. At least they are being boxed with a label indicating that. That such an ado will cost extra is again the result of mercantile operation. A set of 4 EL84, for example, will cost 30 Euro if you ask for industry tubes but set you back 70 Euro if you are being handed a “matched quartet”. How this “matching” is done will normally not be disclosed. How well it works out: that shall be the subject of the following pages. For those of us who regard 70 Euro as an insult to their virtuosity, **NOS-ware** is available. These would be tubes that have not only miraculously be hidden away in basements and warehouses but actually were even able to reproduce, and are offered – since many years – with the supplemental encouraging remark: one of the very last originals! Their sound is portrayed as unrivaled, this assessment being supported by the intuitively fair enough reasoning that the old tube experts were scrapped together with the old manufacturing plants. In individual cases that may have been accurate (while not entirely trivial, after all), but it is – frankly – nonsense to conclude that a tube would be better just because it has spent 50 years in the basement without use. It will *possibly* deliver exactly the desired sound; just as possibly it will, however, sound worse than a low-cost industrial tube. You will only know after you’ve bought it.

It is difficult for the buyer to verify whether a particular tube indeed hails from ancient stock or is merely a modern el-cheapo imitation. Internet-forums about “faked tubes” are of some help here. Whether a tube does meet the given requirements will be revealed (subjectively) by listening tests and (objectively) by measuring its data. At this point we shall not yet investigate to which extent a conclusion from one to the other is legitimate – let’s look at the technical data first. According to conventional wisdom, most important are plate dissipation and transconductance (plus of course the socket needs to fit). Plate dissipation = maximum load (e.g. 30 W), transconductance = gain (e.g. 5 mA/V). That, however, will not be good enough to select a power tube – in a guitar amp there are further criteria to base this choice on.

♣ Only the lifespan of the tube stands in the way of that this range not extending to exactly 0 Hz.

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To **assign the power-needs** is relatively easy as long as we look at the bare essentials: low power = EL-84, 6V6-GT; medium power = 6L6-GC, 5881, KT-66, EL-34; high power = KT-88, 6550. There are of course more tubes, and some tubes were/are offered in several power categories (e.g. 6L6-GB vs. 6L6-GC), but we will not go into that here. Similarly, a discussion about the **proof voltage** will be omitted – the corresponding statements in the datasheets are too obscure and contradictory.

Power tubes are rated with about 10 – 50 W regarding the **maximum power dissipation at the plate**. This value must *not* be mistaken for the power output of the amplifier! There are 100-W-amps that draw their output power from 2xEL34 ($P_{a,\max}$ = 25W), and there are 40-W-amps using 2x6L6-GC ($P_{a,\max}$ = 30W). **Fig. 10.5.6** shows the output- and transmission-characteristics of the most important power tubes. All curves are for $U_{g1} = U_{gk}$ = 0V, i.e. for full drive level. Applying positive control-grid voltages, it would in principle be possible to achieve even higher plate-currents but the usual driver stages are of too high an output-impedance for this. Besides the control-grid voltage, it is also the screen-grid voltage that determines the shape of the output characteristic. In order to be able to compare, we choose U_{g2} = 350 V, although of course not all amplifiers operate with this voltage value. The GE-datasheet even specifies as little as 285 V for the 6V6-GT – but that didn't hold back Fender to subject the 6V6-GT in the Princeton to a proud 415 V.

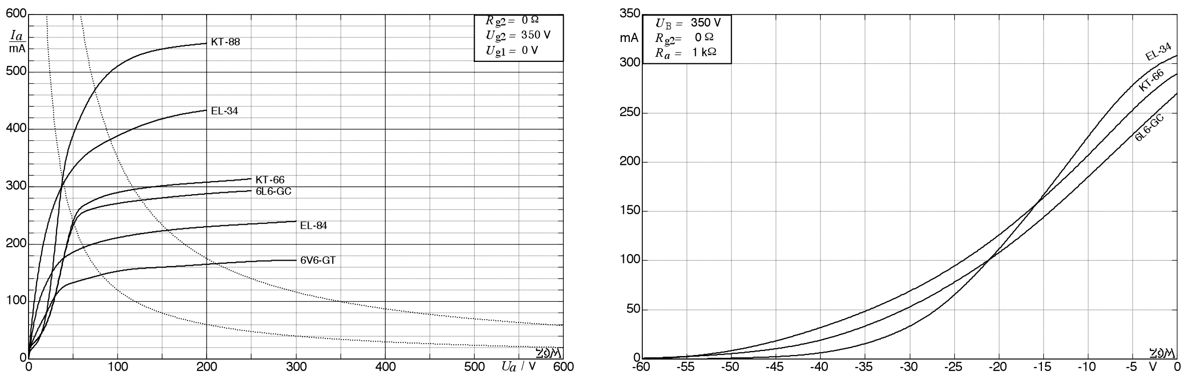

Fig. 10.5.6: Output characteristics (left) und transmission characteristics (right) of some power tubes.

We can see from Fig. 10.5.6 that – for comparable operating conditions – the maximum plate-currents differ quite substantially, after all. The transmission characteristics, as well, show pronounced individuality, and therefore a KT-66, for example, must only be switched for an EL34 after suitable modifications in the circuitry. In any case, it is important to bear in mind that such characteristics remain general, simplifying illustrations.

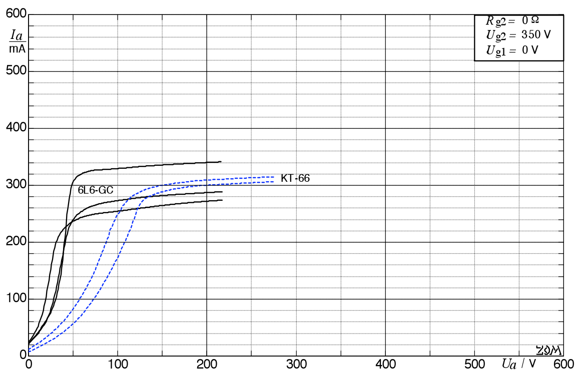

Fig. 10.5.7: Measured output characteristics

Fig. 10.5.7 proves this via measurements with 3x6L6-GC and 2xKT-66. Given just the data-sheet info, similar characteristics in all 5 tubes would be expected – reality is quite different, however. In some circles, the looks (i.e. the shape of the glass container) of a tube will be given more attention than the actual electrical function. Comparison tests that are not considering significant electrical differences as those shown above are thus not only not helpful, but just plain useless. More on that in Chapters 10.5.11 and 10.11.

The following **table** compiles some tube data. The respective year was taken from literature i.e. it does not necessarily indicate the true time when the respective tube was first issued to the market. The transconductance (mA/V) depends much on the specific operating point, and therefore the given value is for rough orientation only: detailed information is offered by the characteristic curves (Chapter 10.11).

The maximum permissible plate dissipation is also to be seen for orientation only: the specification in the datasheets of different manufacturers deviate to some extent, and moreover, back in the day the specification was done using two different standards: **Design Center System**, and **Design Maximum System** (in brackets, compare to Chapter 10.5.9).

Type	$P_{a,\max}$ / W	mA/V	Manufacturer	Year
6V6	12 (14)	4	RCA	1937
6V6-G	12 (14)	4	RCA	1941
6V6-GT	12 (14)	4	RCA	1944
6V6-GTA	12 (14)	4	RCA	1962
6L6	19 (---)	5.3	MOV ⇒ RCA	> 1933
6L6-G	19 (---)	5.3		> 1936
6L6-GA	19 (---)	5.3		> 1943
6L6-GB	19 (22)	5.3		
6L6-WGB	20 (23)	5.3	Tung-Sol	1950
6L6-GC	--- (30)	5.3		1954
5881	23 (---)	5.3	Tung-Sol	1950
7027	25 (---)	6	RCA	1958
7027-A	--- (35)	6	RCA	1959
6550	35 (---)	11	RCA	1962
6550-A	--- (42)	11	GE	1972
KT-66	--- (25)	6.3	Marconi	1956 (> 1937)
KT-66	--- (25)	7	MOV	1977
KT-77	--- (25)	11	MOV	1977
KT-88	--- (35)	11	MOV, GEC	1957
KT-90	--- (45)	11	Ei	
EL84	12 (---)	11	Philips	Ca. 1955
EL34	25 (---)	12	Philips	Ca. 1952
EL51	45	11	Philips	1953
EL151	60	13	Telefunken	1943
QB3.5/750	250	4	Philips	

Table: Power-tube data-sheet information: maximum plate dissipation and transconductance.

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