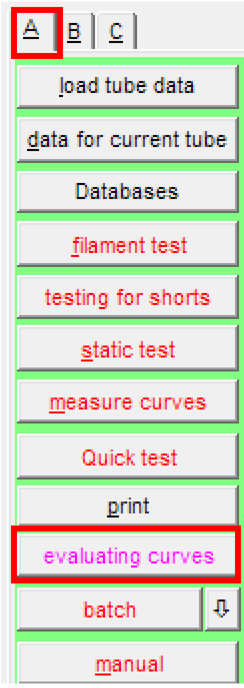
RoeTest – Computer Tube Tester / Tube Measuring System
(c) - Helmut Weigl   www.roehrentest.de

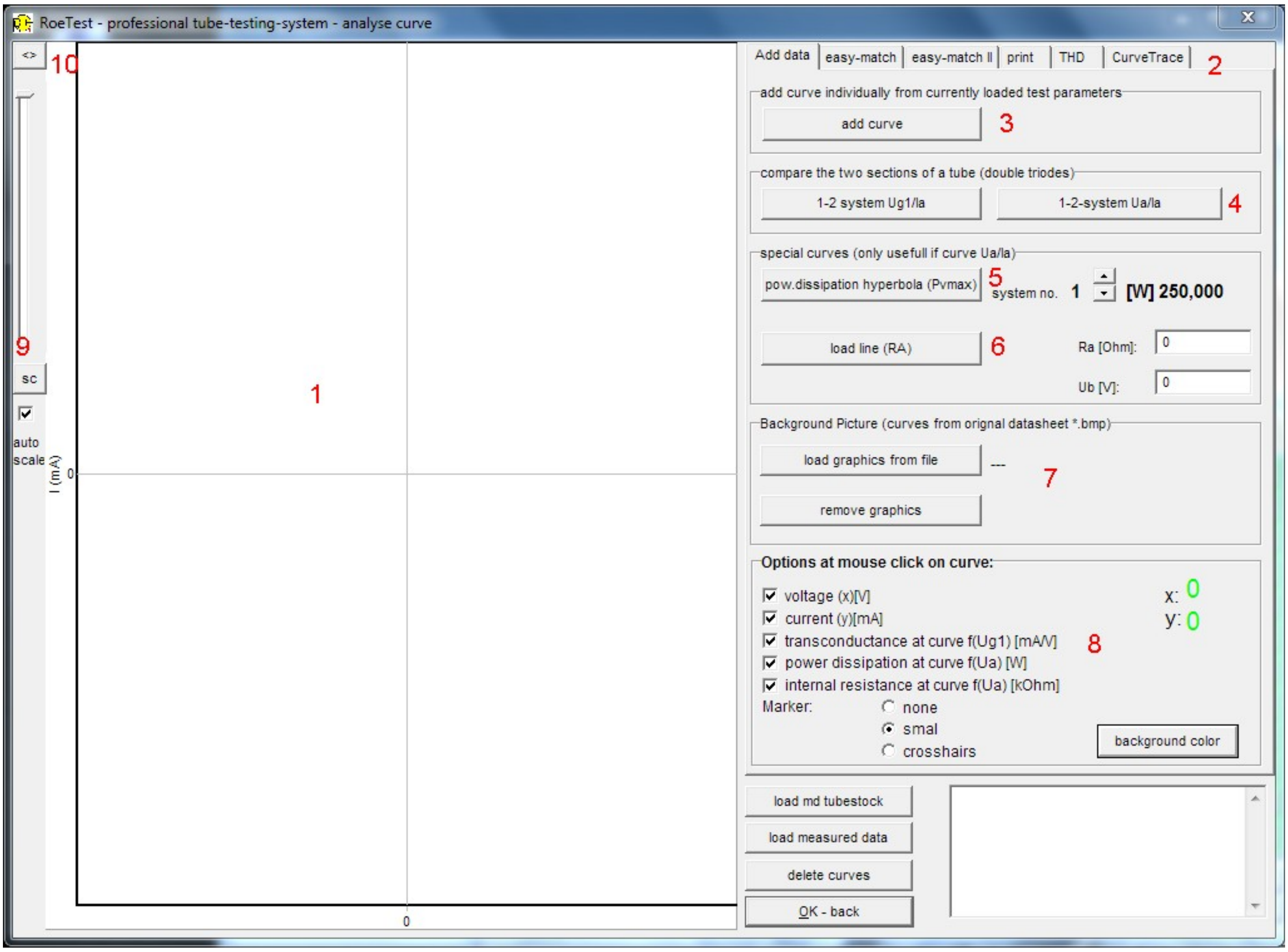
translation to english by Gerhard Oed (thank you very much to him)

Interpreting/evaluating characteristic curves

The window for interpreting curves can be activated using the following button:



Evaluating window:

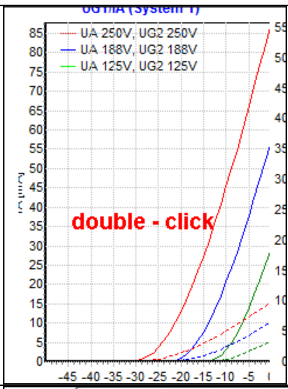
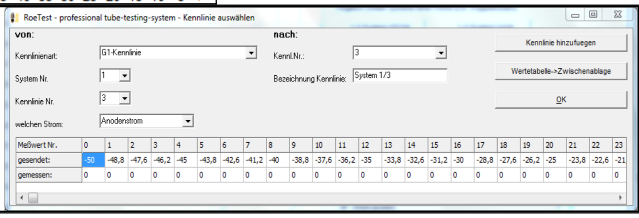
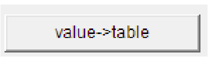
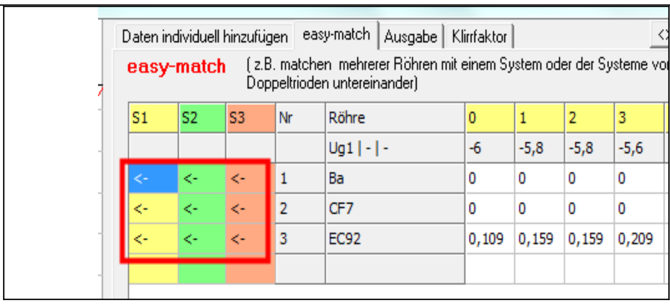
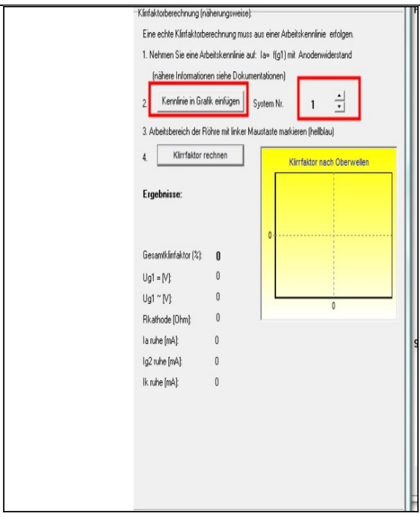


1 Into this graphic up to 20 characteristic curves may be copied (note: only curves of the same type – either input- or output characteristic curves can be used)
2 Different functions can be selected using the tabs. The picture shows the tab 'add data'. This means adding curves to the graphics.
3 Copy individual characteristic curves from the main window to the analyzing graphics window
4 Copy characteristic curves of double triodes to the analyzing graphics window
5 Draw power dissipation hyperbola (only for $f(U_a)$)
6 Draw output resistance line (only for $f(U_a)$)
7 background graphics (see also separate tip 'comparing curves with datasheet', file: 'Kennlinie mit Datenblatt vergleichen_EN.pdf')
8 Settings for text output for marking curves
9 Change graphics resolution (slider and button <sc> for parametrical input, or automatic scaling)
10 Enlarge / shrink window

remarks to tab CurveTrace: See also separate documentation 'curve trace special' (file: 'Kennlinienaufnahme spezial_EN.pdf')

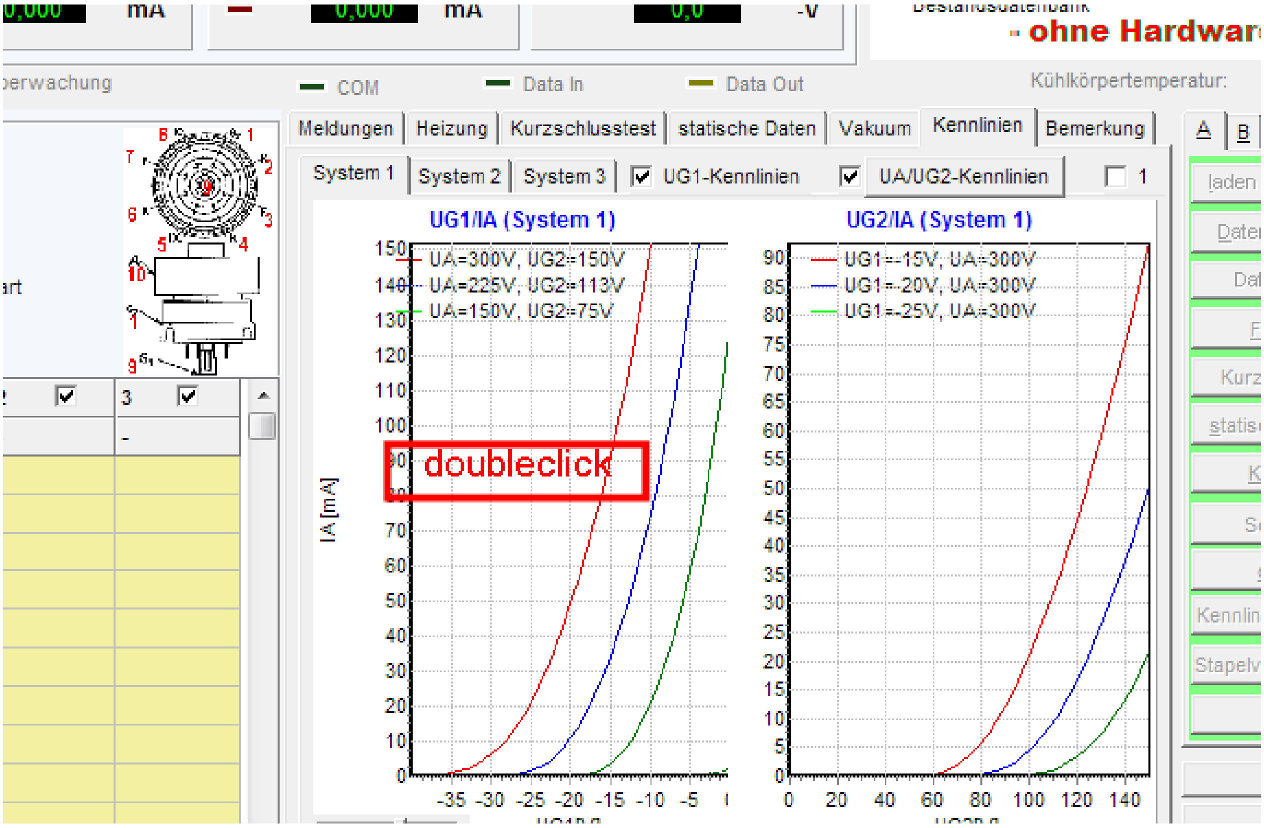
To interpret the characteristic curves they must first be copied from the main window to the analyzing window.

There are different methods to do that:

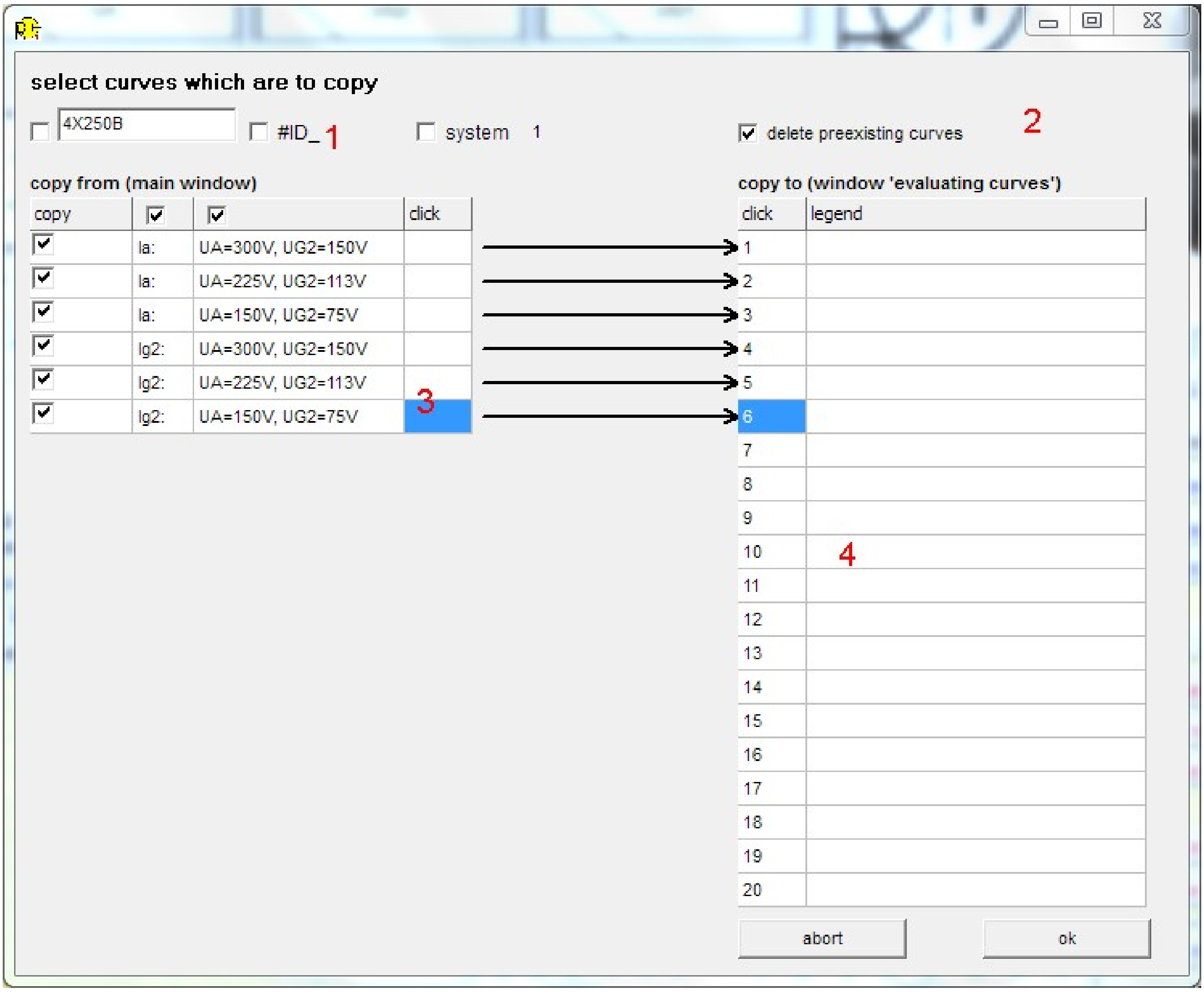
Double click in the main window on a graphic representation -> a options window opens with possibility of choosing legends and curves to copy (see following text)	
Individually using button 3 here you can select exactly which characteristic curve shall be copied	
For double triodes use buttons 4	The first characteristic curve of system 1 and system 2 respectively will be copied automatically
From the easy match table when clicking <- (for system 1, 2 or 3) First the data must have been copied to the easy-match table. This may be done either using the button  or automatically by batch processing. The table can also be filled with stored measure data.	
From the distortion factor calculation using the button in this case the input curve (I_a and I_{g2}) are copied Note: The true distortion factor can only be calculated using a **work resistance** curve. What this means is described in another hint. How to record this curve with the RoeTest is described below.	

Double click on a characteristic curve in the main window:

The simplest method to copy characteristic curves from the main window into the analyzing window is to double click on the graphics to be copied:



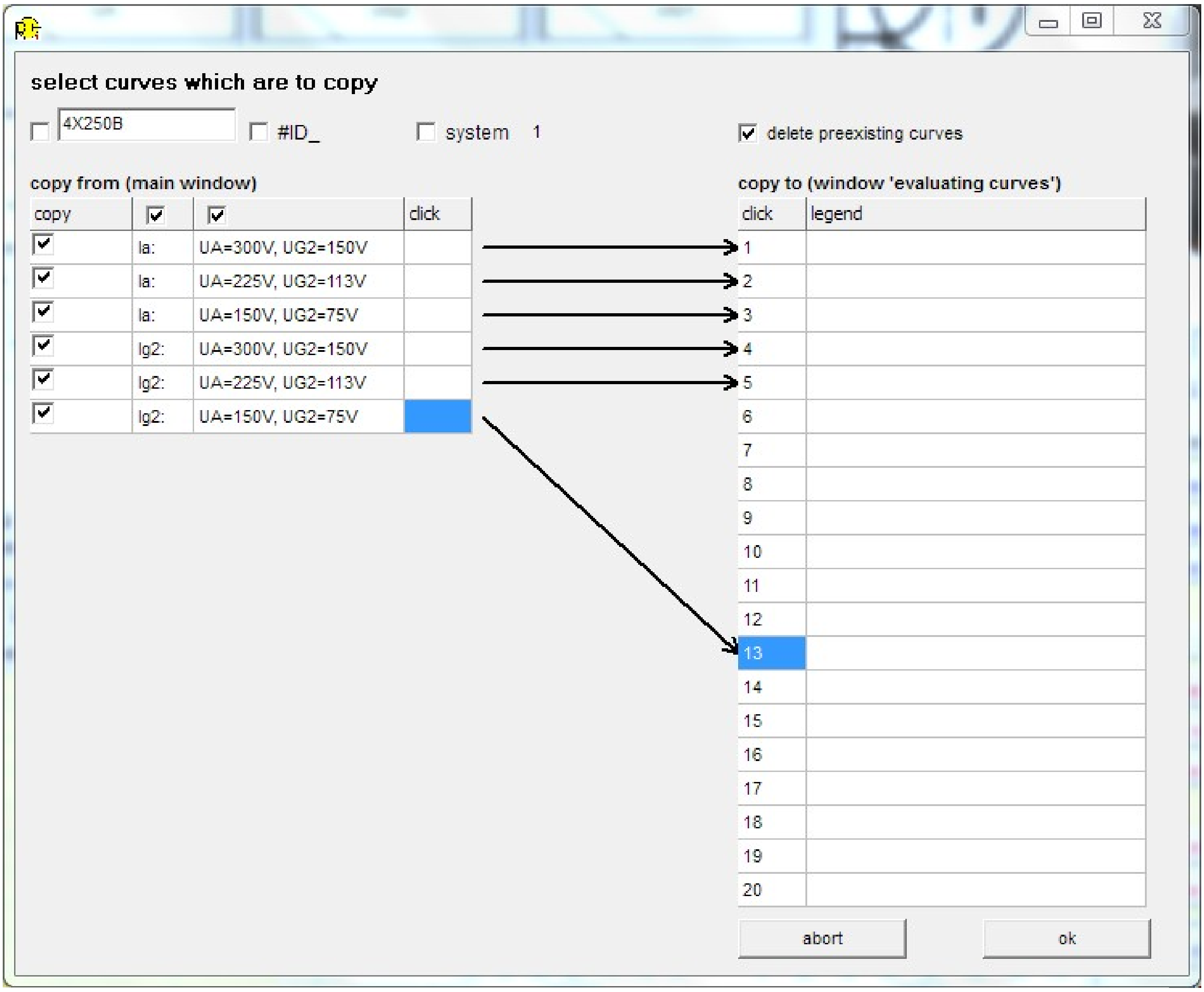
The following option window will then be opened:



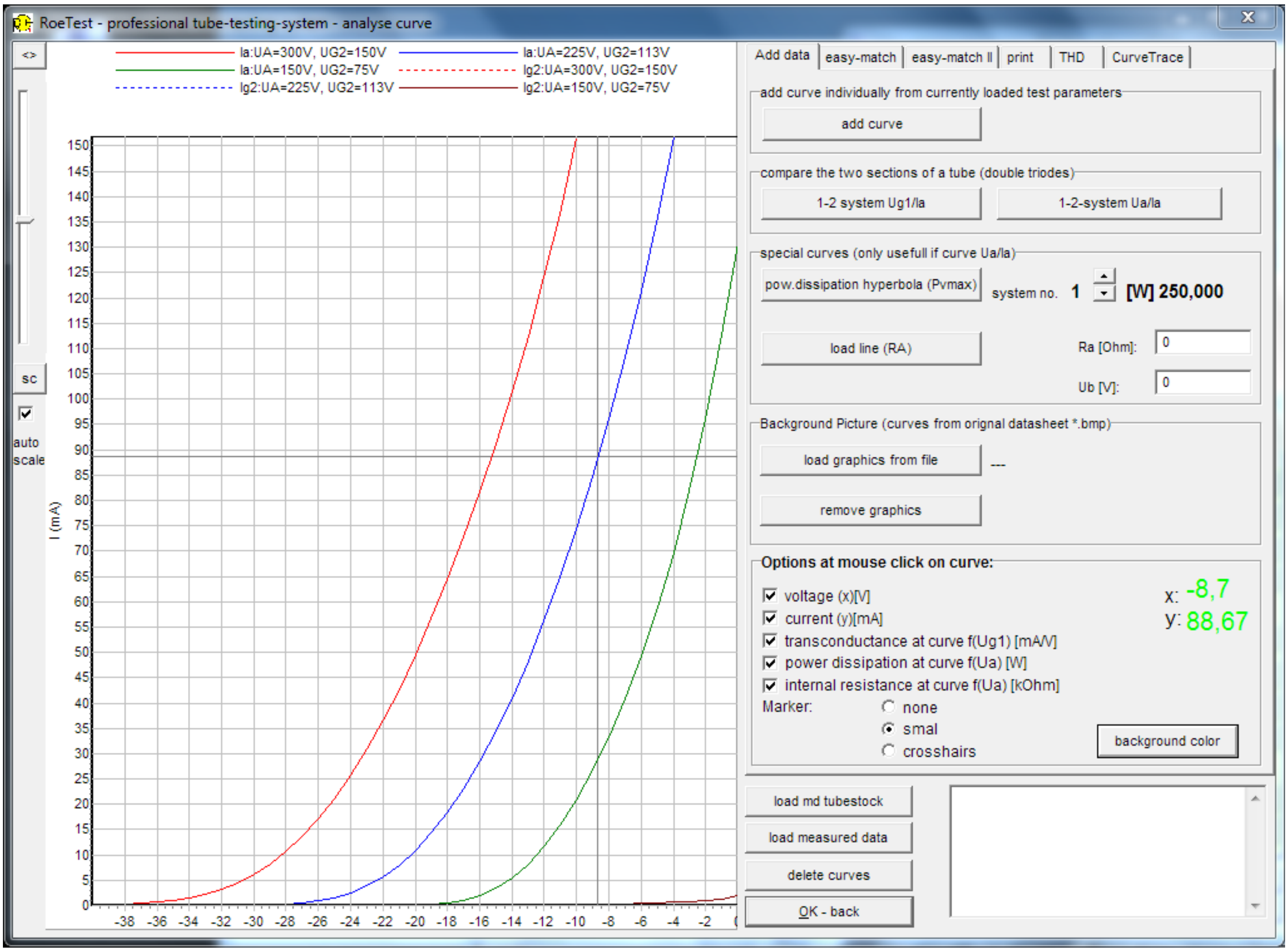
1 On the left side the legend of the curve to be copied can be defined and changed. You can also select which curve/s shall be copied to the analyzing graphics.

2 This mark determines whether existing analyzing graphics content will be erased before the copy or if existing data will be kept.

3 A mouse click on the last row in a line from the left table and then moving the mouse to the right table will show an arrow to which position of the analyzing graphics the curve will be copied. Already defined curves in the analyzing graphics show up with their respective legends on the right side.
So when needed: Put mouse pointer on last row on line in left table. Click left mouse button (and then release it). Move mouse to first row of desired line of the right table. Left click mouse again. The arrow will change accordingly:



In this example the last selected characteristic curve (in the last line of the left table) will be copied to position (line) 13 in the right table. Pressing the <ok> button will then copy the selected characteristic curve(s) to the analyzing graphics:



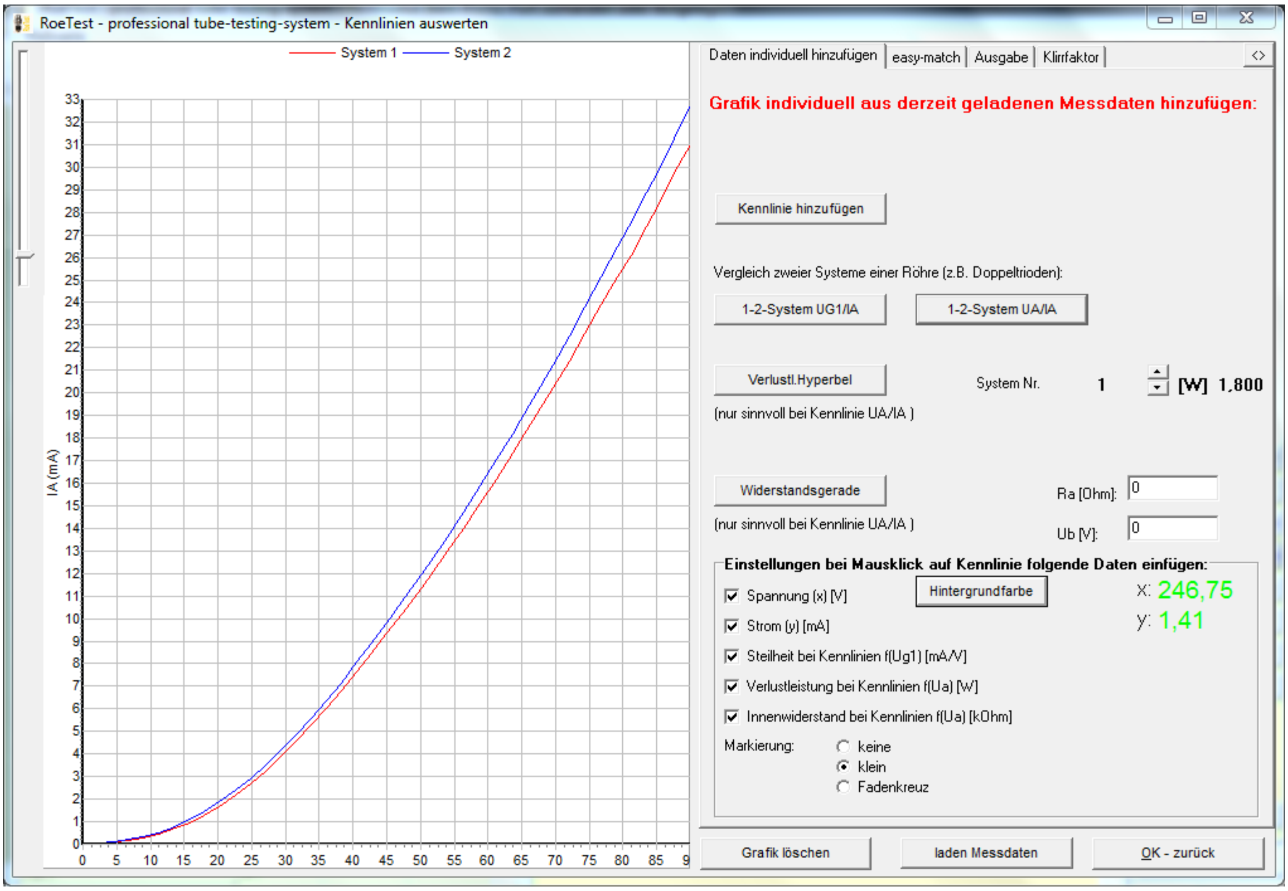
RoeTest - professional tube-testing-system - analyse curve
Ia:UA=300V, UG2=150V
Ia:UA=225V, UG2=113V
Ia:UA=150V, UG2=75V
Ig2:UA=300V, UG2=150V
Ig2:UA=225V, UG2=113V
Ig2:UA=150V, UG2=75V
I (mA)
sc
auto scale
Add data
easy-match
easy-match II
print
THD
CurveTrace
add curve individually from currently loaded test parameters
add curve
compare the two sections of a tube (double triodes)
1-2 system Ug1/Ia
1-2-system Ua/Ia
special curves (only usefull if curve Ua/Ia)
pow.dissipation hyperbola (Pvmax)
system no. 1
[W] 250,000
load line (RA)
Ra [Ohm]: 0
Ub [V]: 0
Background Picture (curves from orignal datasheet *.bmp)
load graphics from file
remove graphics
Options at mouse click on curve:
voltage (x)[V]
current (y)[mA]
transconductance at curve f(Ug1) [mA/V]
power dissipation at curve f(Ua) [W]
internal resistance at curve f(Ua) [kOhm]
x: -8,7
y: 88,67
Marker:
none
smal
crosshairs
background color
load md tubestock
load measured data
delete curves
OK - back

In the following some examples follow showing what is possible using the analyzing window:

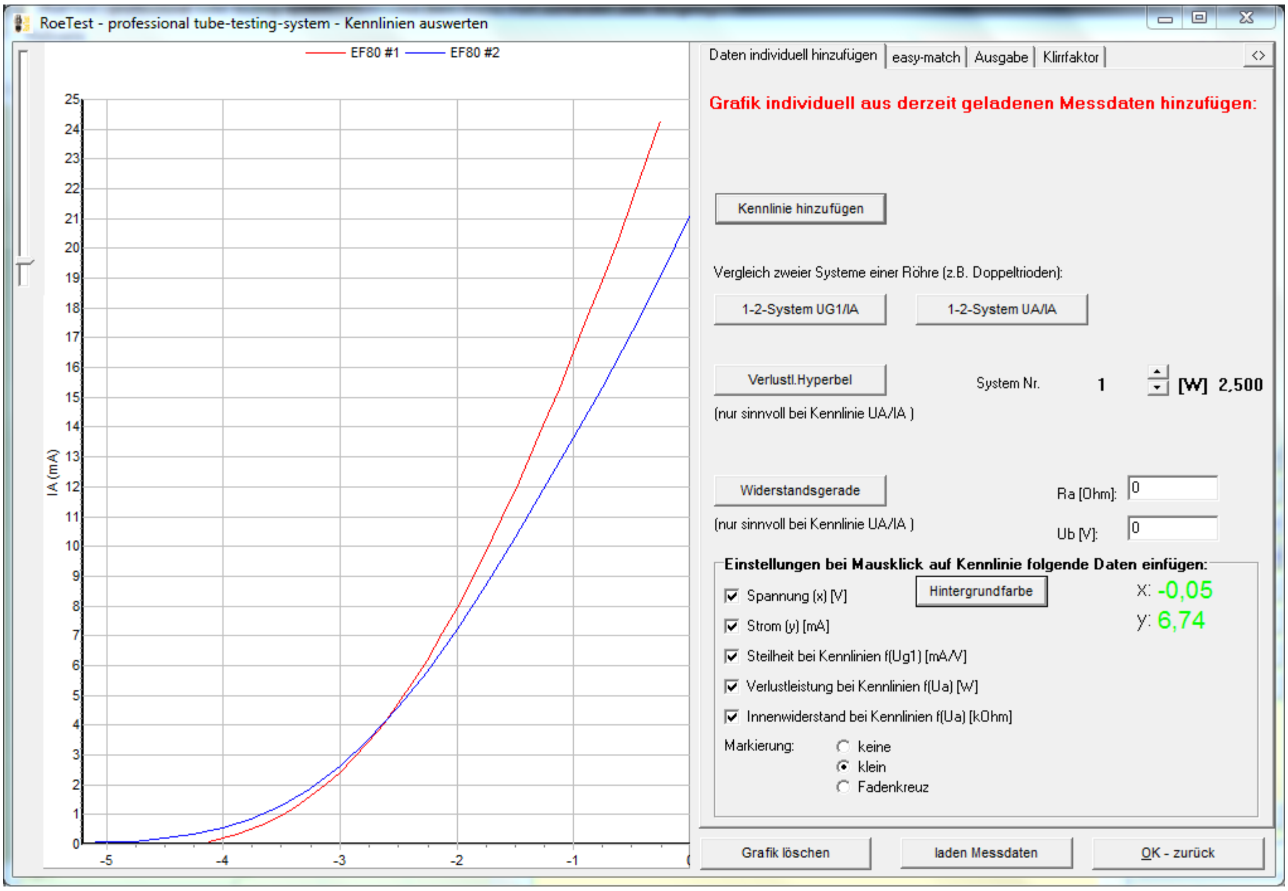
a) Comparison of characteristic curves:

Up to 20 characteristic curves can be shown and compared. Possible are for example:

Ÿdifferent systems of a tube (e.g. double triodes)
Ÿdifferent tubes of same type (e.g. EL84) to get 2 or more comparable ones (I.e to **match** tubes)
Ÿdifferent tubes of different type (e.g. EF80, EF89) for example
Ÿto show the difference between control type tubes and non-control type ones

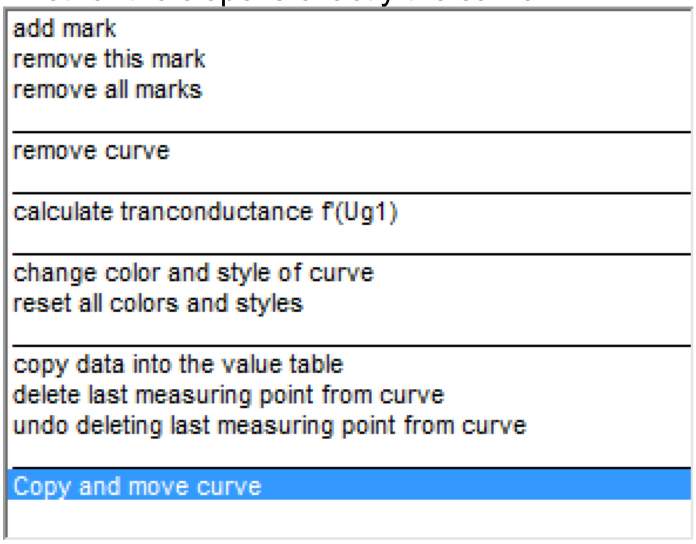


Two systems of an E88CC



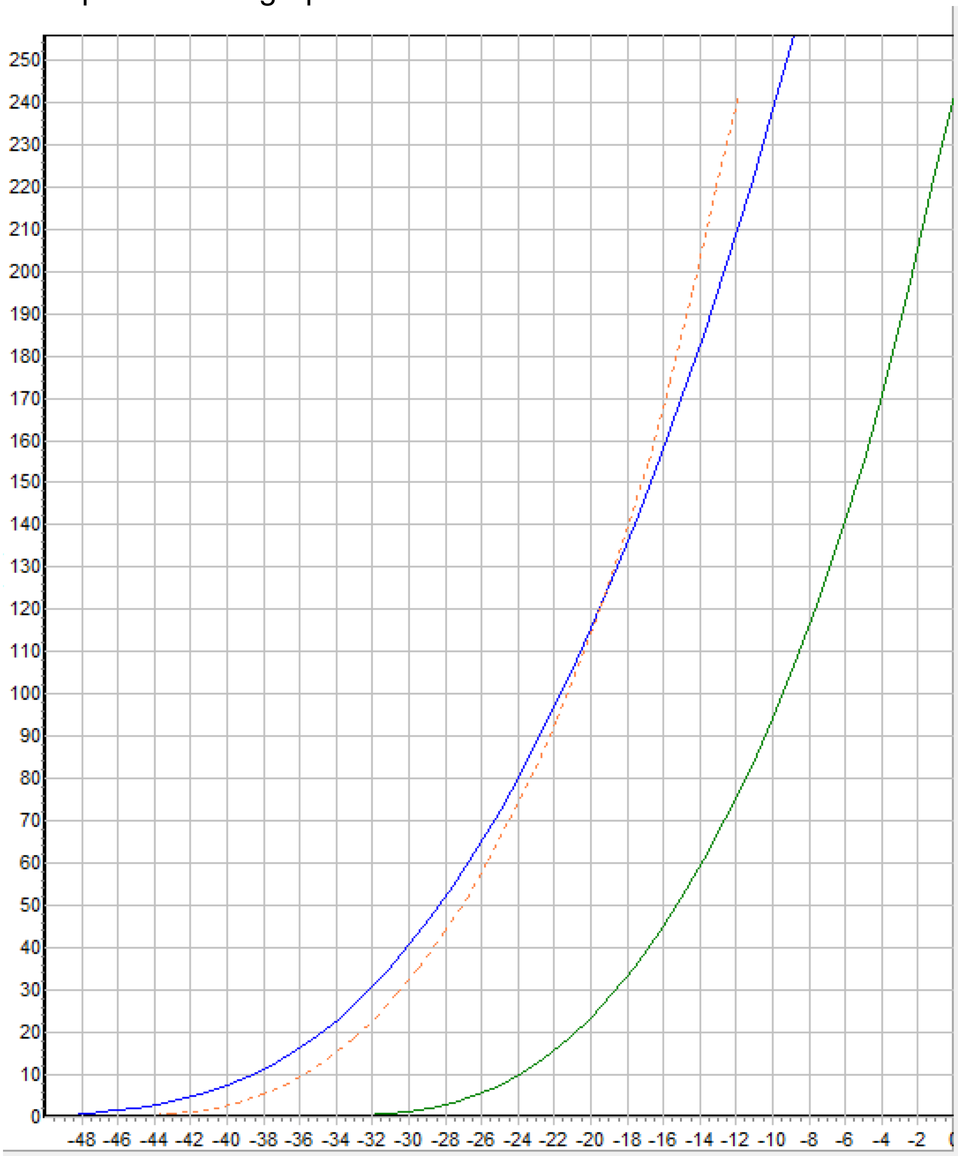
Comparison of two EF80 – the tubes do not match well. If the match decision were only made at one point (at -2.5V) a wrong decision would have been made. This example shows that matching of tubes is only meaningful when comparing the characteristic curves in total.

Incidentally, you can use the context menu to copy a characteristic curve and move it in horizhontal direction. The characteristics can be superimposed and compared to see whether the slope is exactly the same:



A copy of the curve you clicked is created, which is displayed in orange color. The copied curve is attached to the mouse pointer and can be moved left and right. If you click the graphic again with the mouse, the curve is stored at the current mouse position.

example in below graphics:

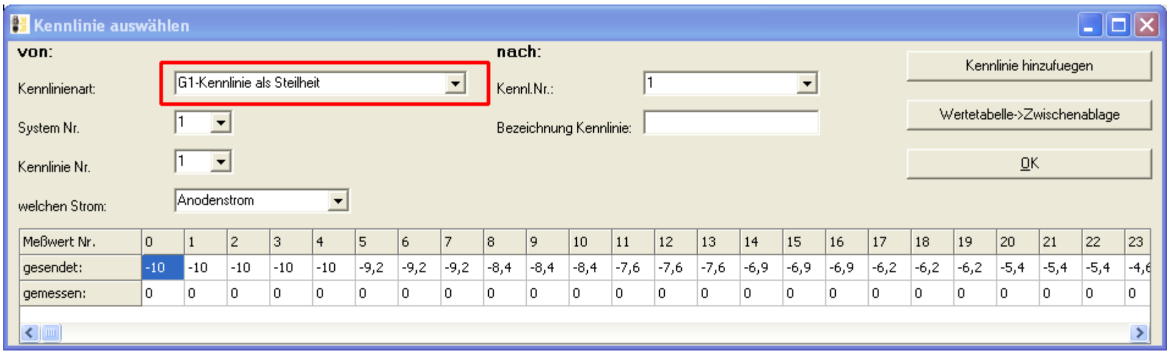


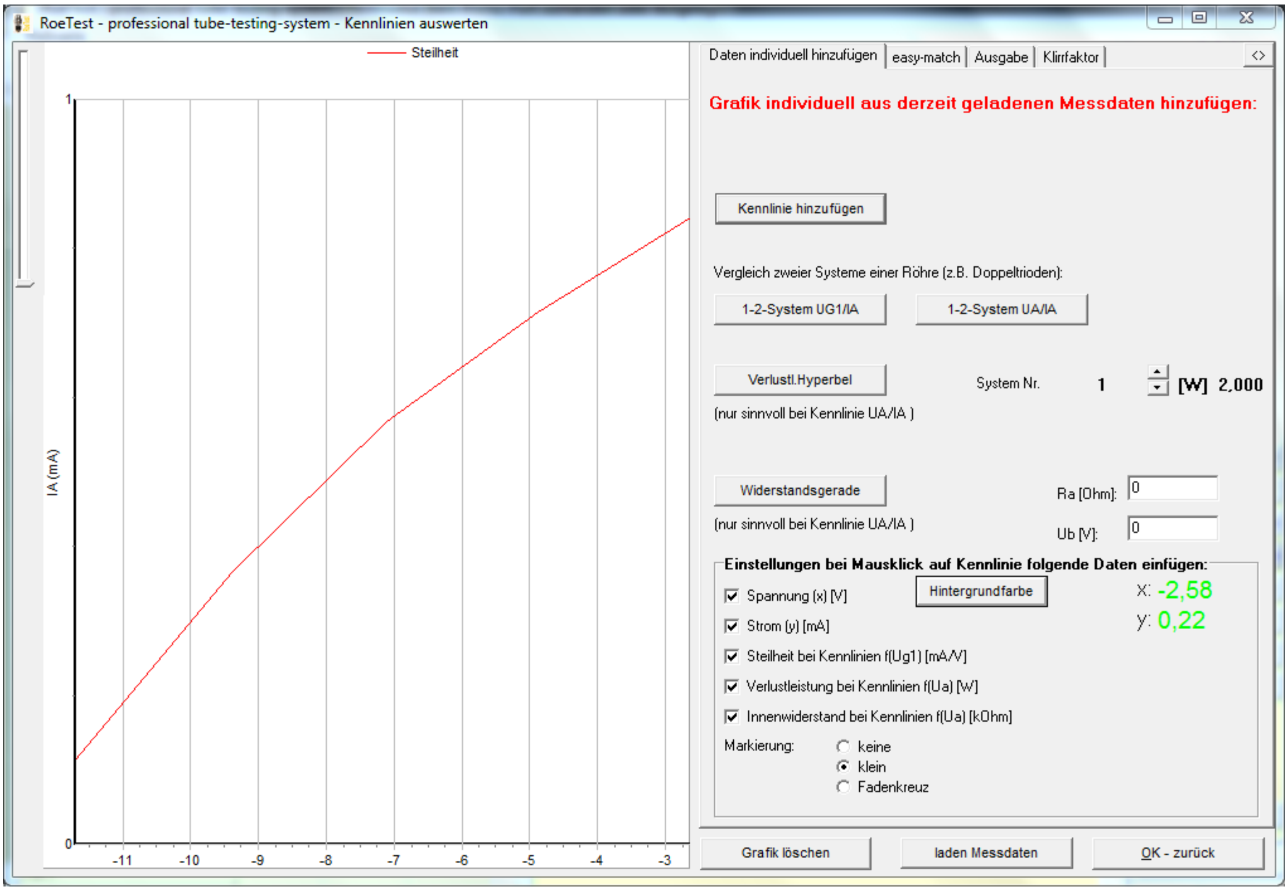
The green curve was clicked and "copy and move" selected in the context menu. The copied orange curve was then placed over the blue curve. This example also shows how the eyes can be fooled. At first glance, the blue and green curves look exactly parallel. In fact, there is a small discrepancy, which can be seen from the copied orange curve.

b) Transconductance characteristic curve:

From a G1 characteristic curve it is possible to calculate a transconductance characteristic curve.

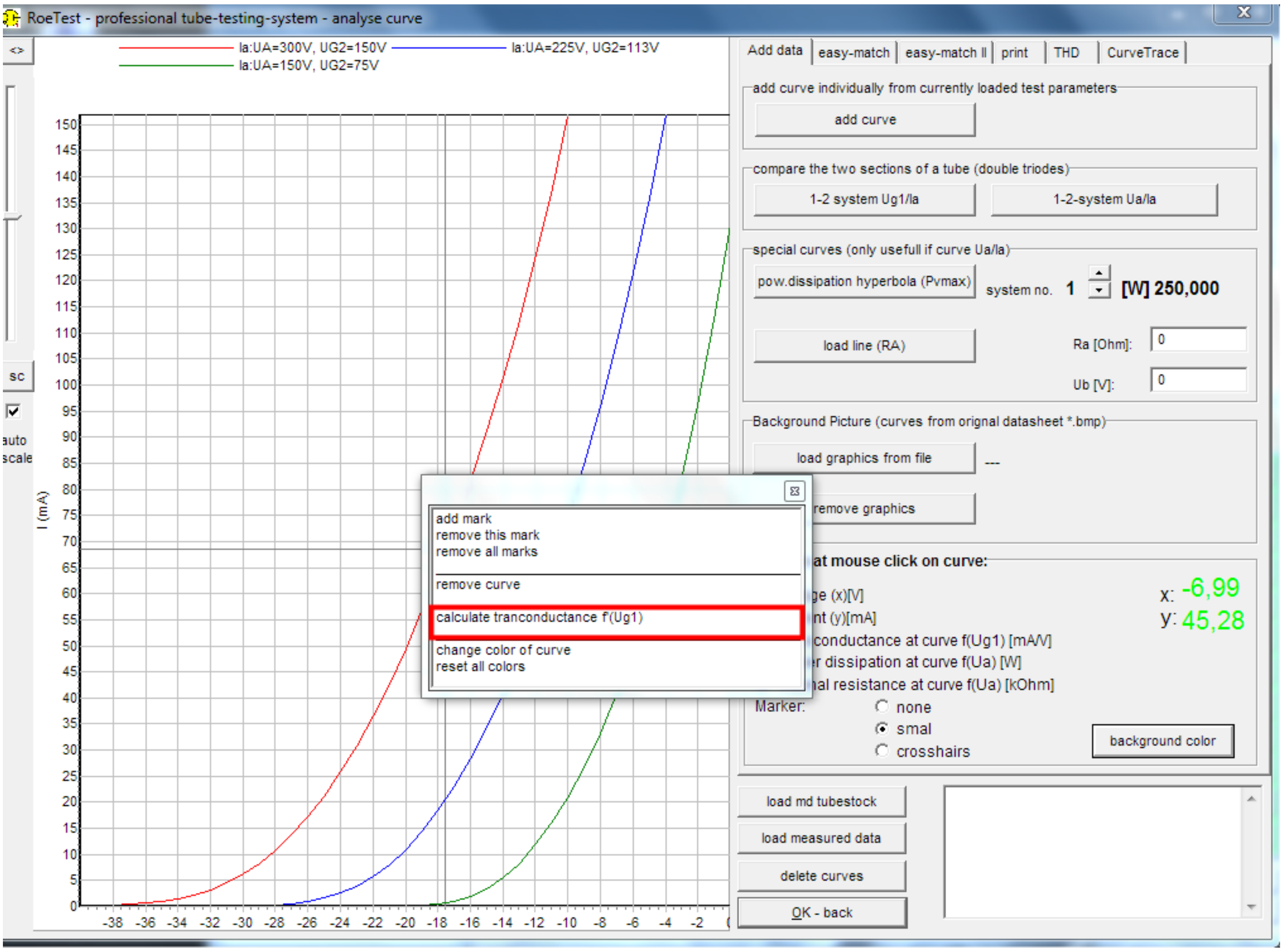
First possibility:



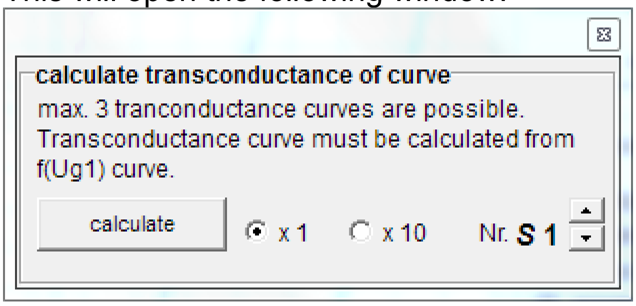


Note: The characteristic curve is calculated from the measuring sample points. For this reason the curve is **always coherent,** but not flat; there are small bends in it.

Second possibility: - mathematical solution
Clicking on a curve will open a context menu. There you select 'calculate transconductance f(Ug1)'



This will open the following window:



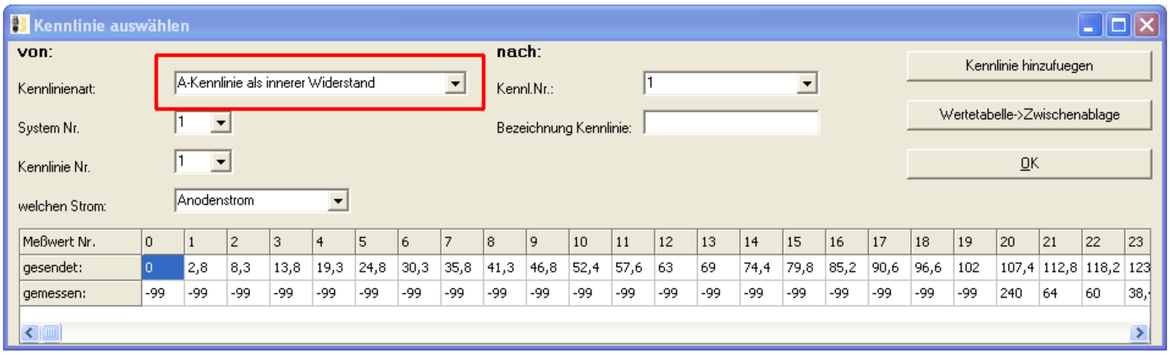
Please always select a f(Ug1)-characteristic curve for that calculation. In principle it is possible to calculate the transconductance from other characteristic curves too. But that would not correspond to the definition of the tube's transconductance.

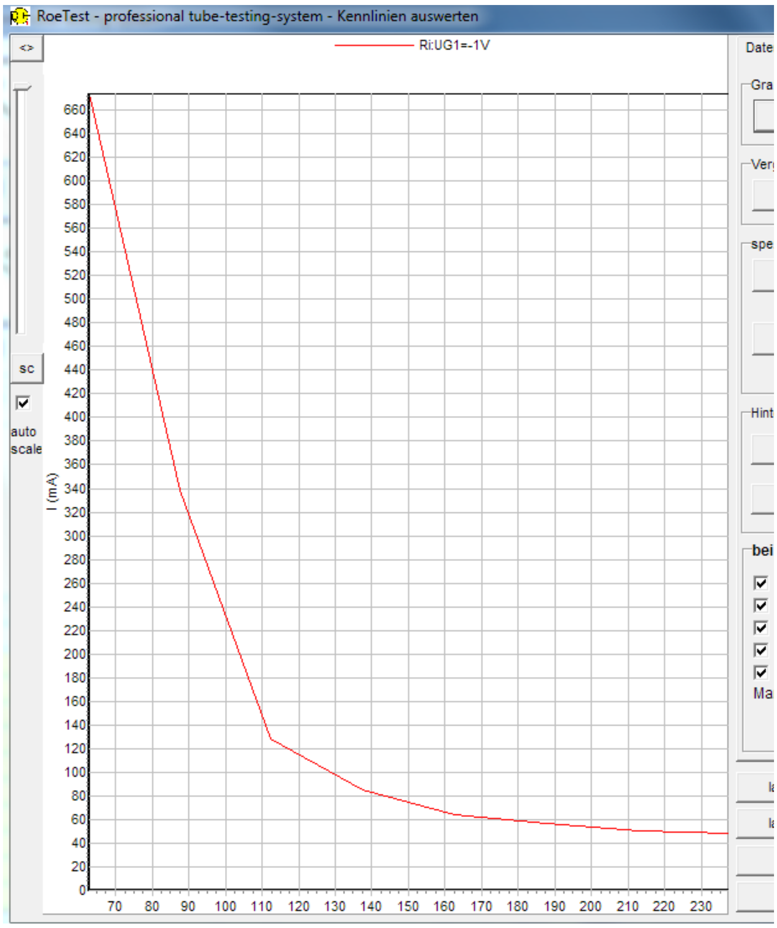
This method converts the initial curve to a functional equation (3rd to 5th degree). Then the first derivative is calculated (this is the transconductance) and then drawn to the diagram. Up to 3 transconductance curves can be shown. It is possible to magnify the transconductance curve (x10) to enhance the presentation.

Advantage of this method: The curves are very smooth. There are some very rare cases where this method will not work properly. In this case please use the method described above (1st method).

c) Characteristic curve of internal resistance:

From an A-characteristic curve (technically the G2-characteristic curve would also be possible – but that is not defined to be the internal resistance) the characteristic curve of the internal resistance can be calculated. This only makes sense for triodes; for pentodes, the current distribution between anode and G2 would spoil the internal resistance characteristic curve (for the theory see e.g. publications from Barkhausen and Kammerloher).

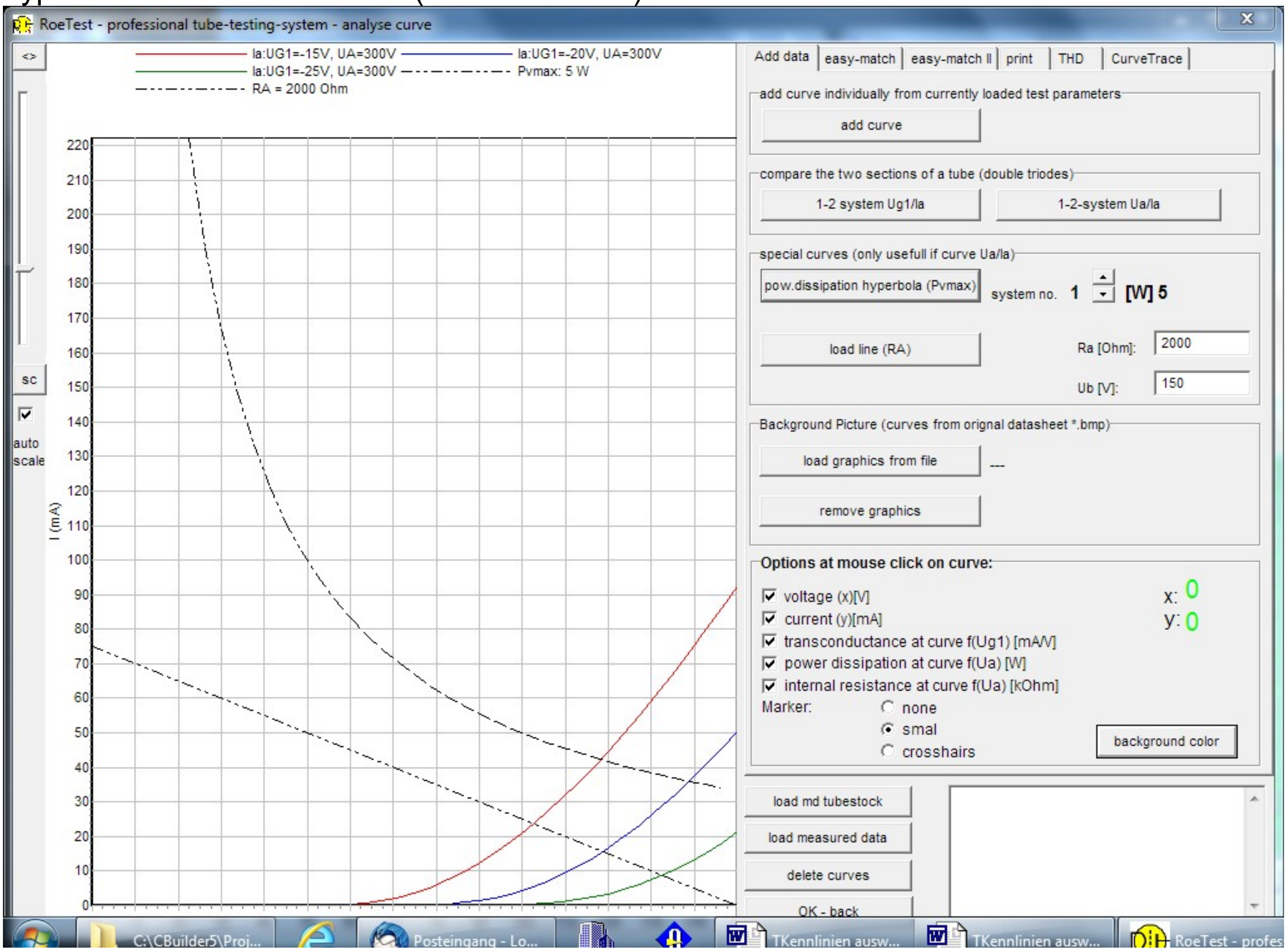




Note: The characteristic curve has large bends. No rounding/automatic smoothing has been applied. In this case you need to construct a smoothed curve by your own (calculating a smoothed curve in this case was not feasible).

d) Power dissipation hyperbola / Resistive Line:

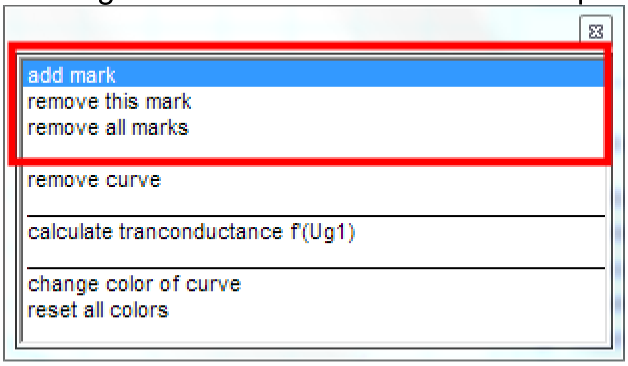
To the characteristic curves f(U_a) you can also draw the power dissipation hyperbola and a resistive line (load resistance):



e) Context menu - Marking the characteristic curves:

To improve readability of the curves and to support marking them there is now a cross hair cursor implemented.

Clicking with the mouse on a curve will open the context menu

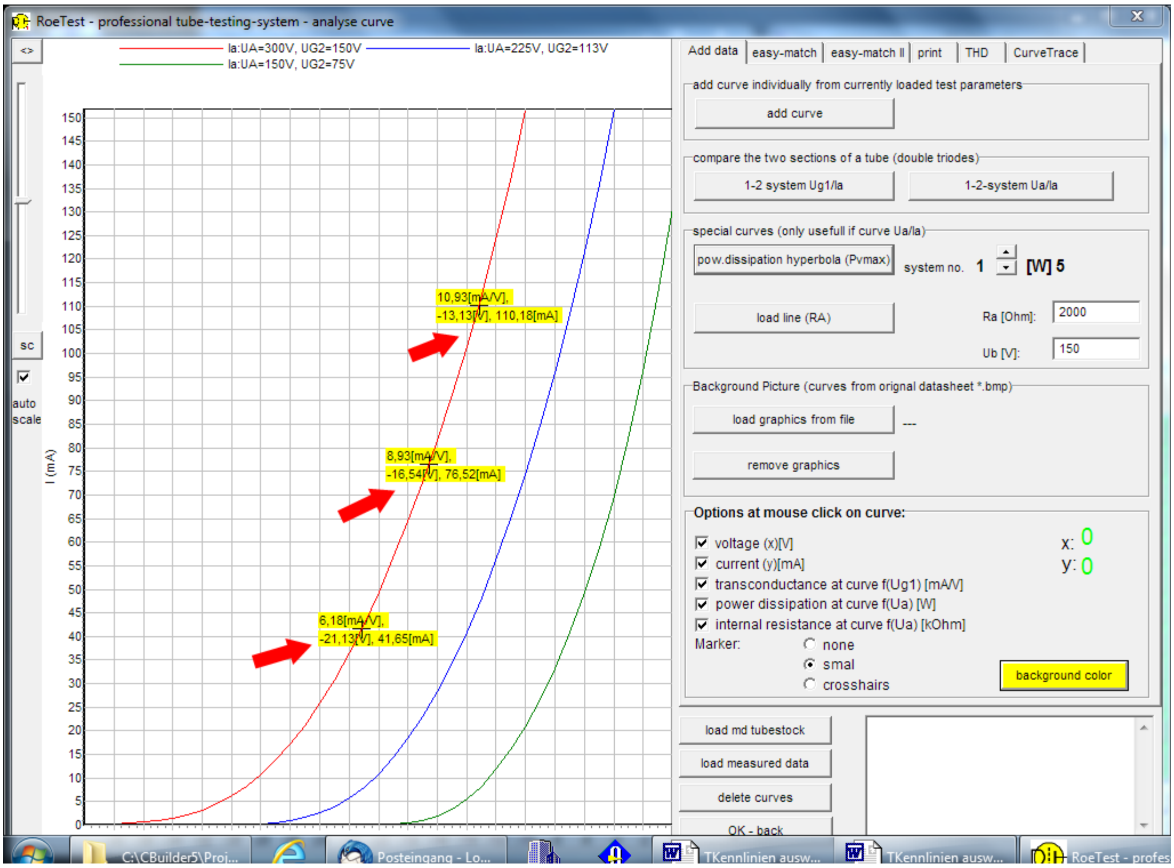


So you can set markings (up to 15) or remove one or all markings.

You can insert the following parameters:

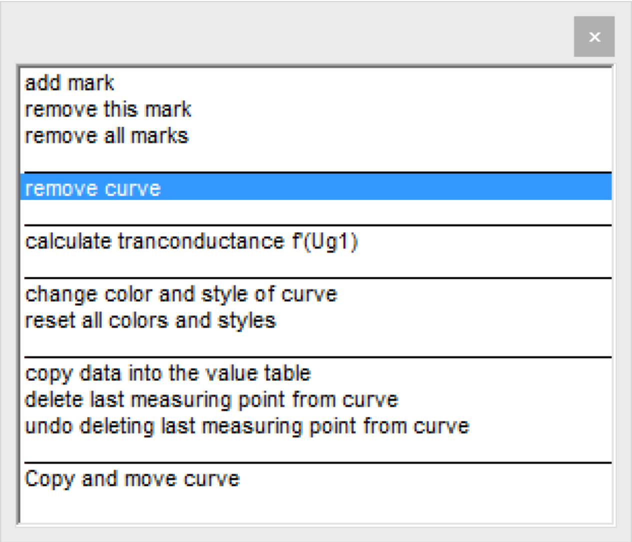
at $f(U_{g1})$: G1-voltage, U_{g1}, I_a, I_{g2}, transconductance
at $f(U_a)$ or $f(U_{g2})$: U_a, I_a, I_{g2}, internal resistance, power dissipation

Additionally a marker or cross hair can be displayed. Even the background color of the text is freely selectable.

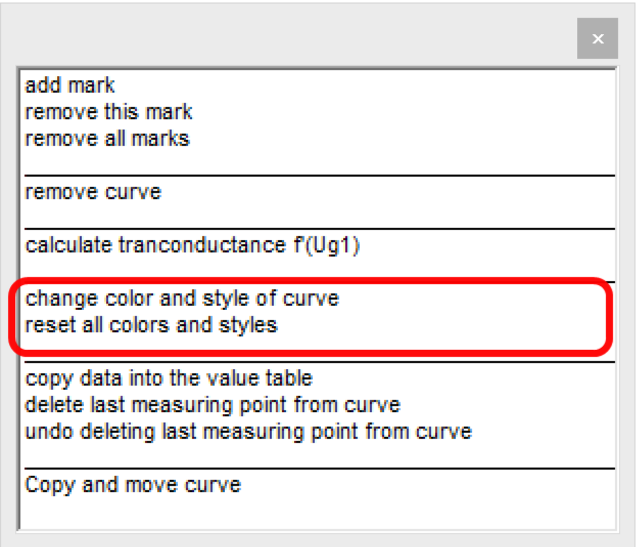


This example shows: U_{g1}, I_a, and transconductance in mA/V

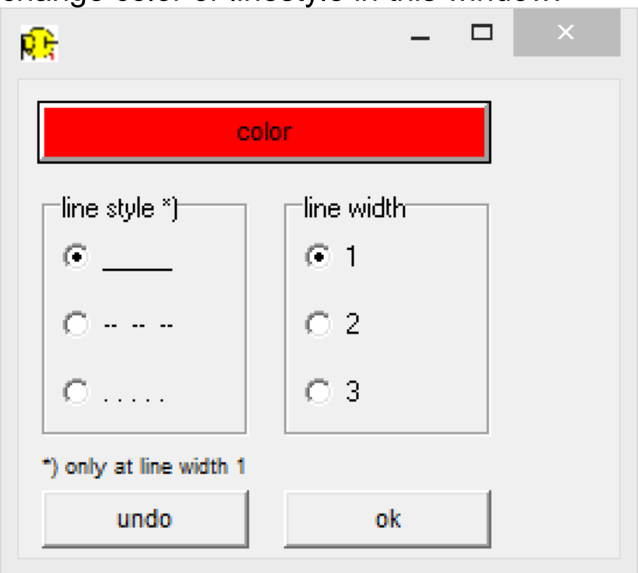
You can delete a curve with the context menu:



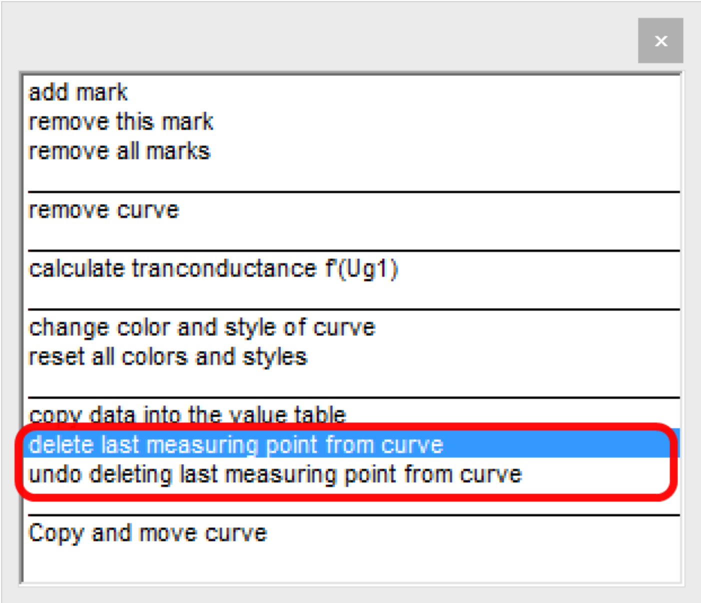
Using the context menu also allows to change the color or style of a curve:



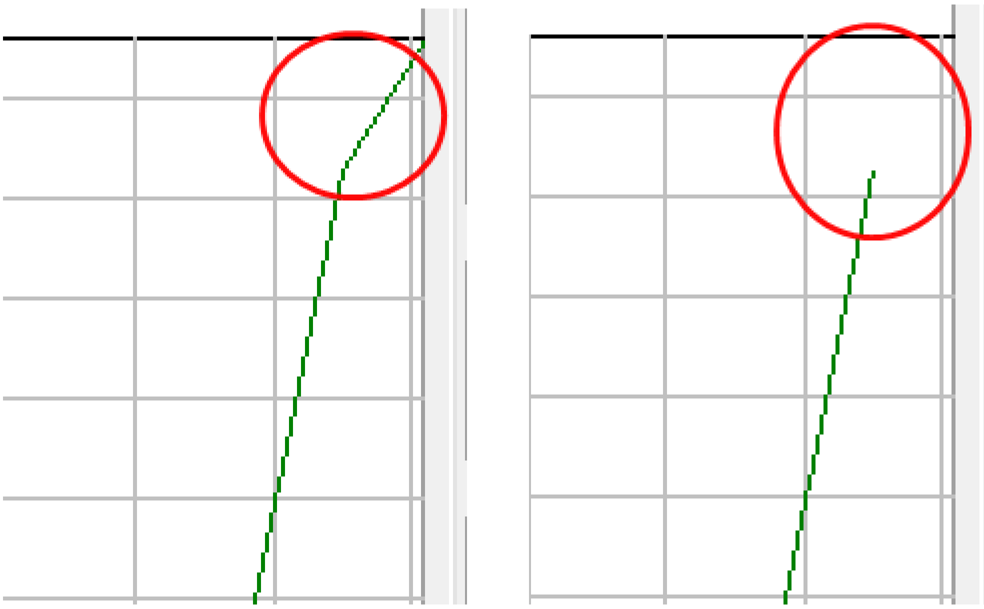
change color or linestyle in this window:



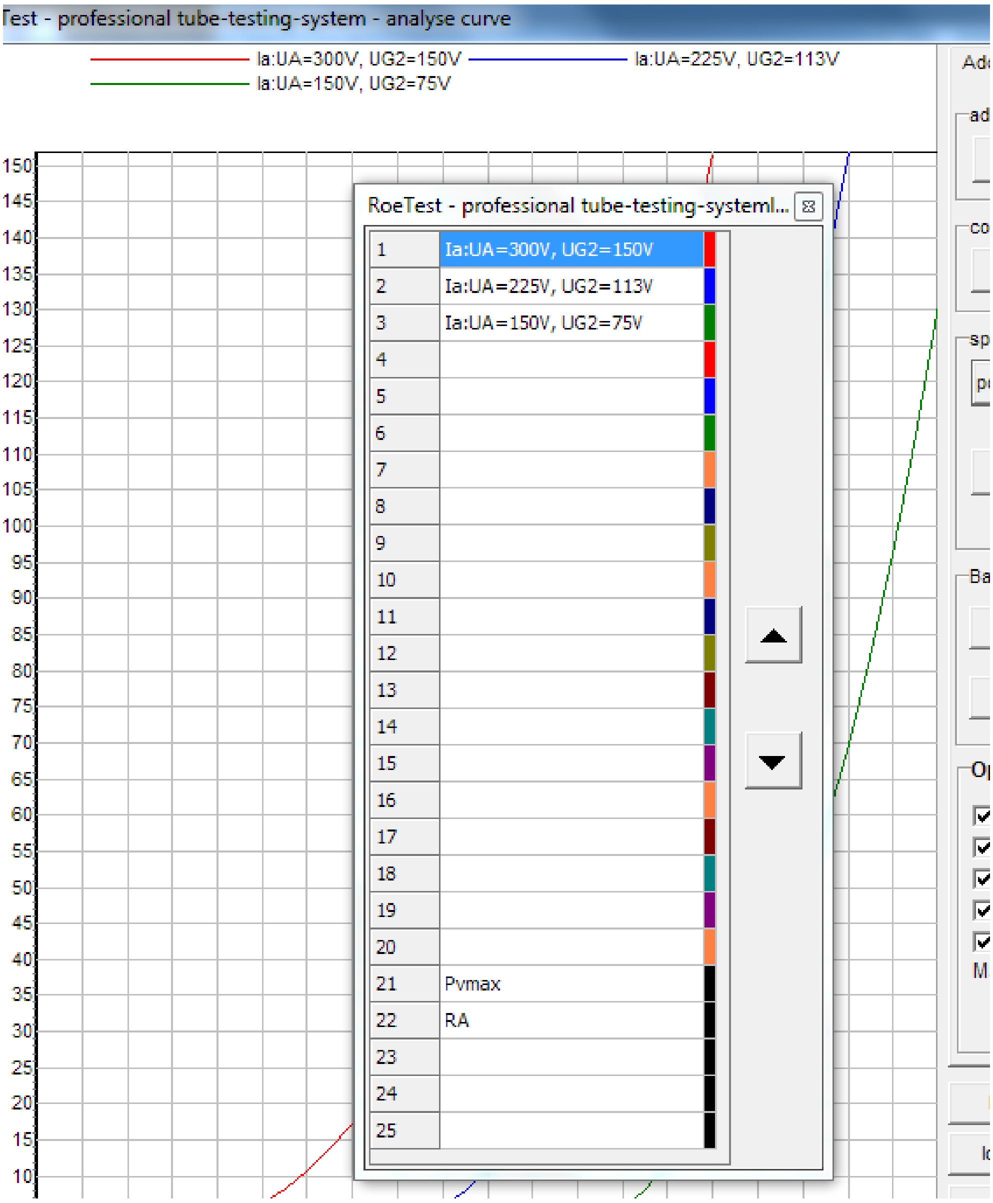
The last measuring point of a characteristic can be deleted and restored:



This is useful if the device can not measure a current over the limit of the measuring range (e.g. Ia> 300mA) and the curve has a kink. The last measuring point can thus be removed.



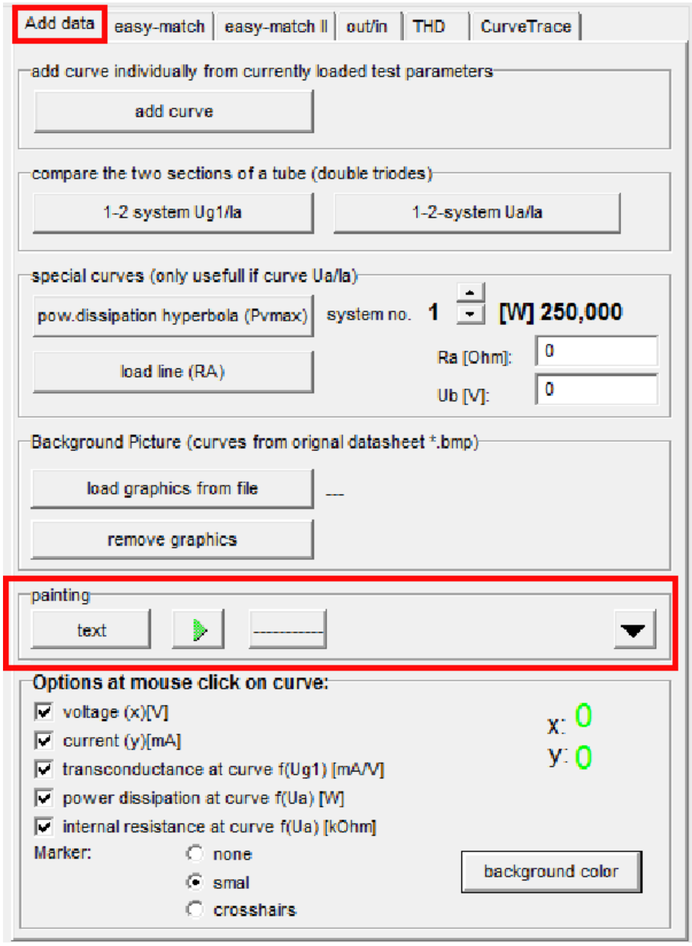
A mouse click on the legend will open the following window:



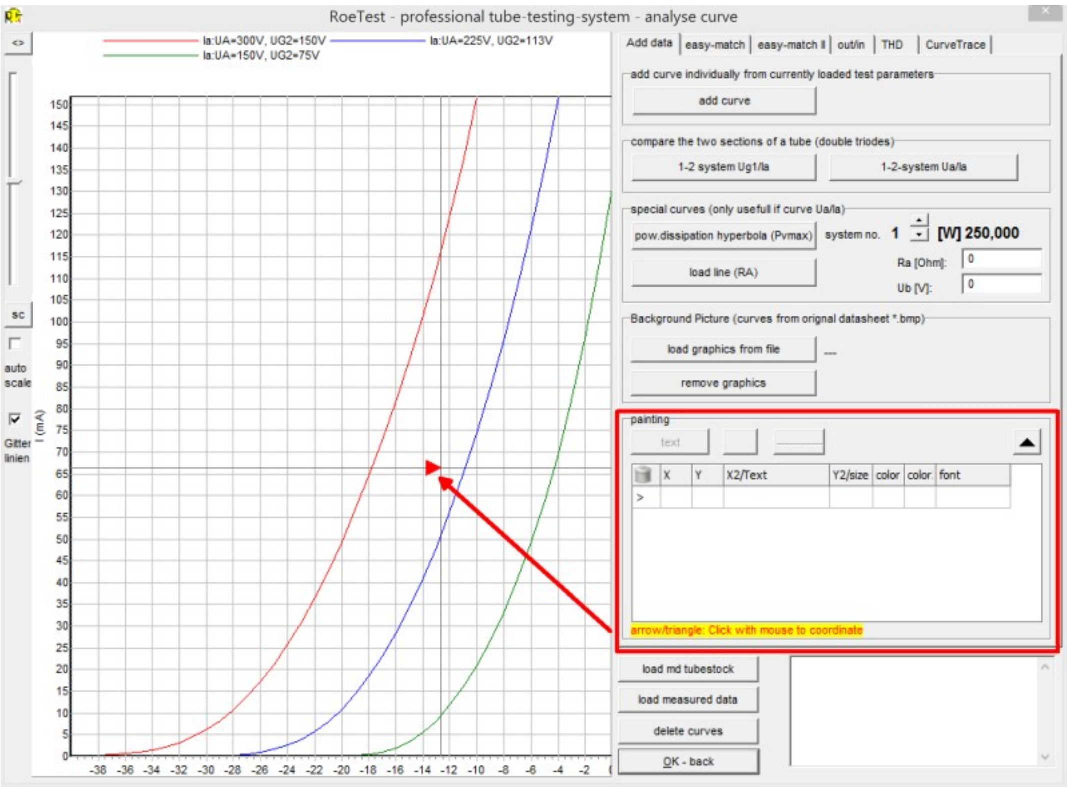
So the legends can be changed or curves can be moved to other positions (Positions 1-20 = normal curves, position 21 = power dissipation hyperbola, position 22 = resistive line, positions 23-25 = transconductance curves; positions 21-25 can also be used for normal curves if the special curves are not required).

f) Zeichenfunktionen

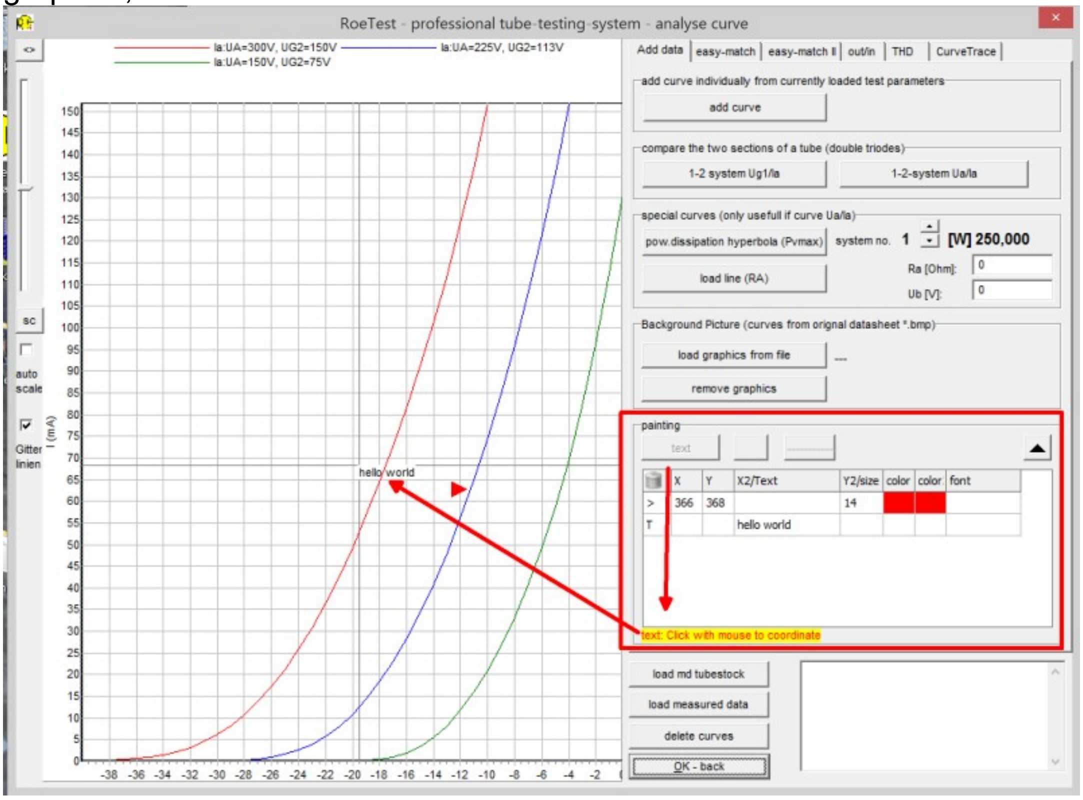
With the painting function you can label the graphics with arrows (triangles), lines and texts.



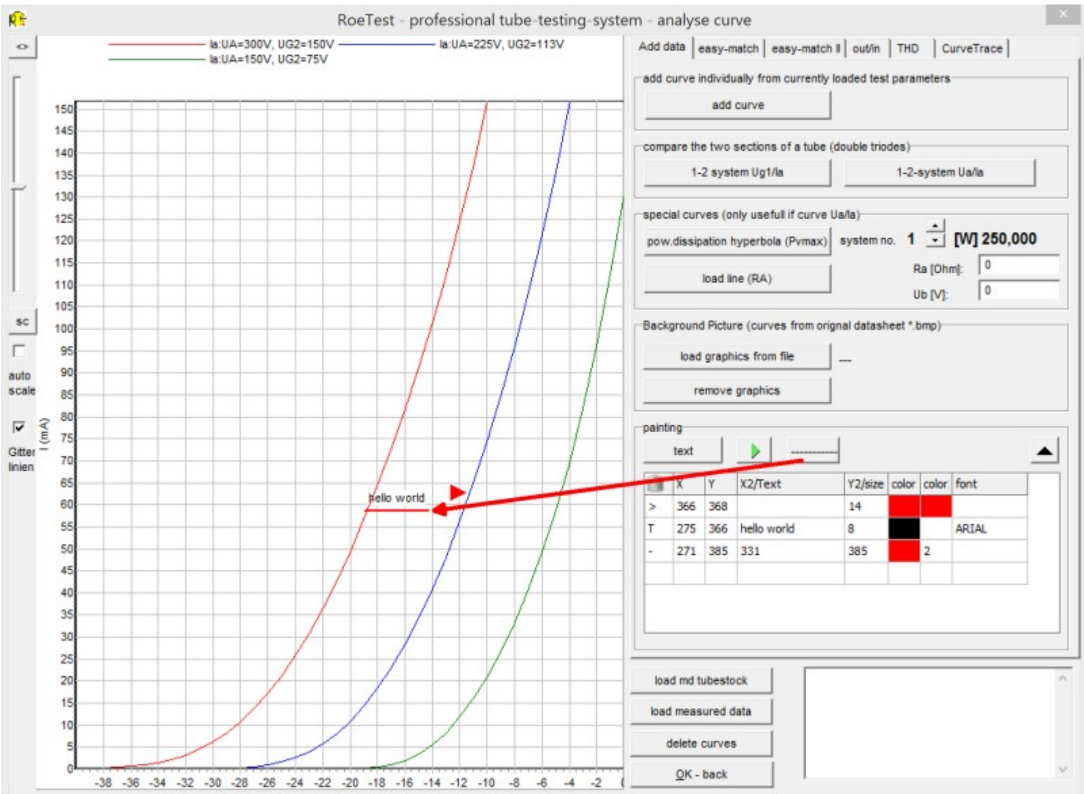
Triangle: Clicking the button 'green triangle' will open the data window for painting. Position the mouse to the desired location in the graphics and then click the left mouse button.



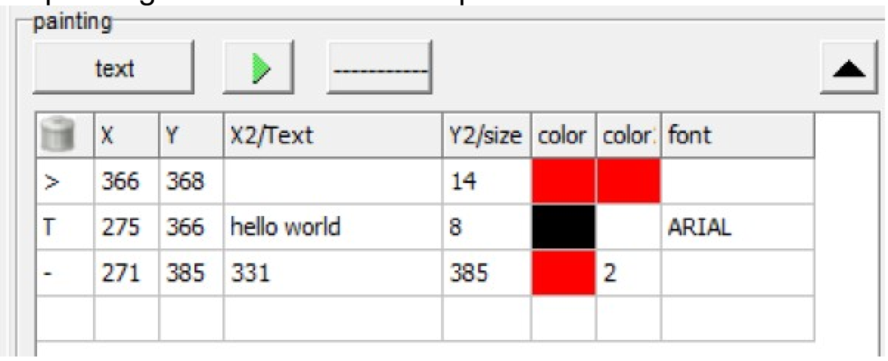
Text: Clicking the button 'text' will open the data window for painting. Enter the desired text in an input area and then position the mouse to the desired location in the graphics, then click the left mouse button.



Lines: Clicking the button '-----' will open the data window for painting. Use the mouse to position the line's starting point and endpoint in the graphics.



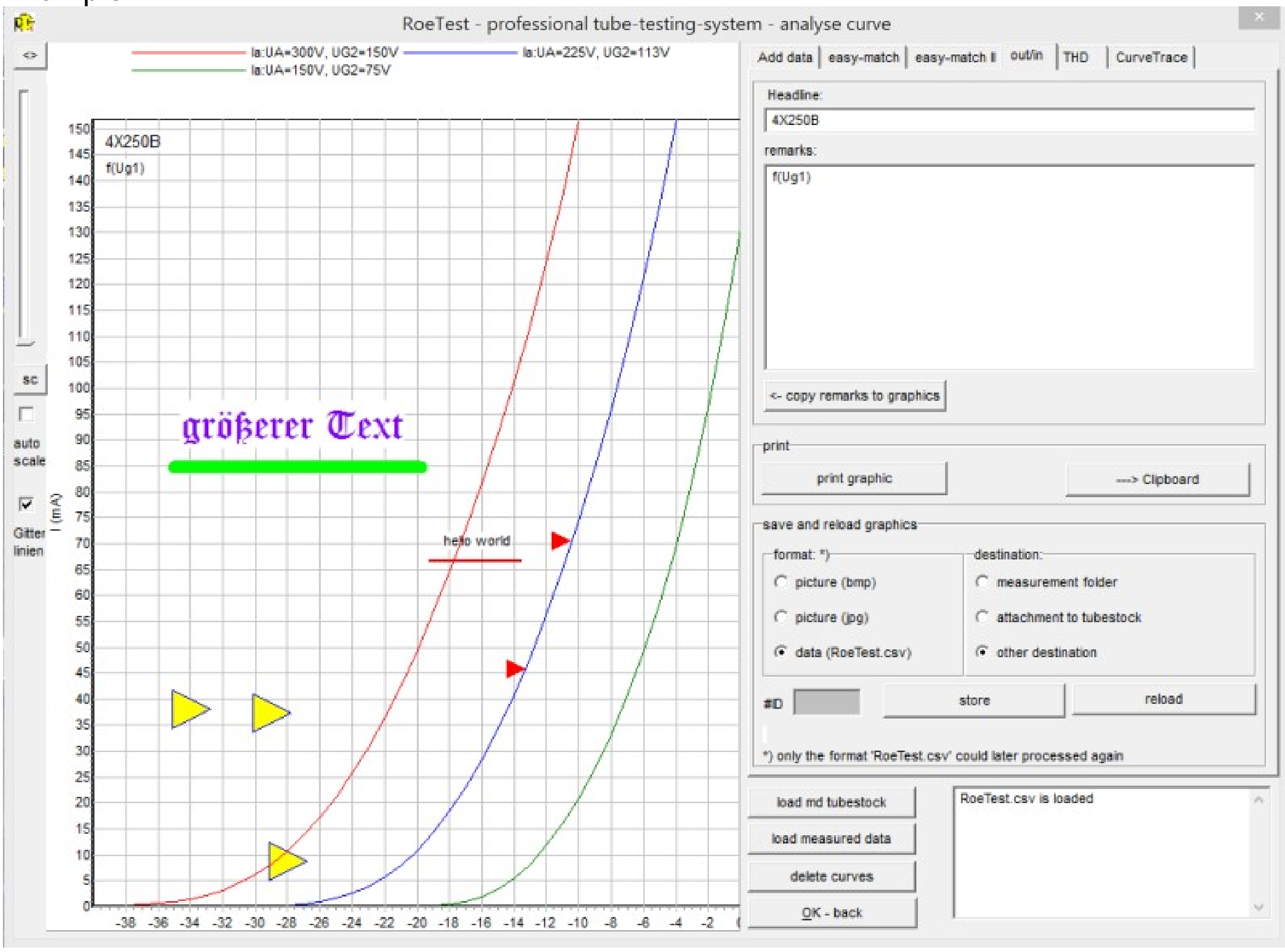
All painting data elements are represented in a table:



	X	Y	X2/Text	Y2/size	color	color	font
>	366	368		14			
T	275	366	hello world	8			ARIAL
-	271	385	331	385		2	

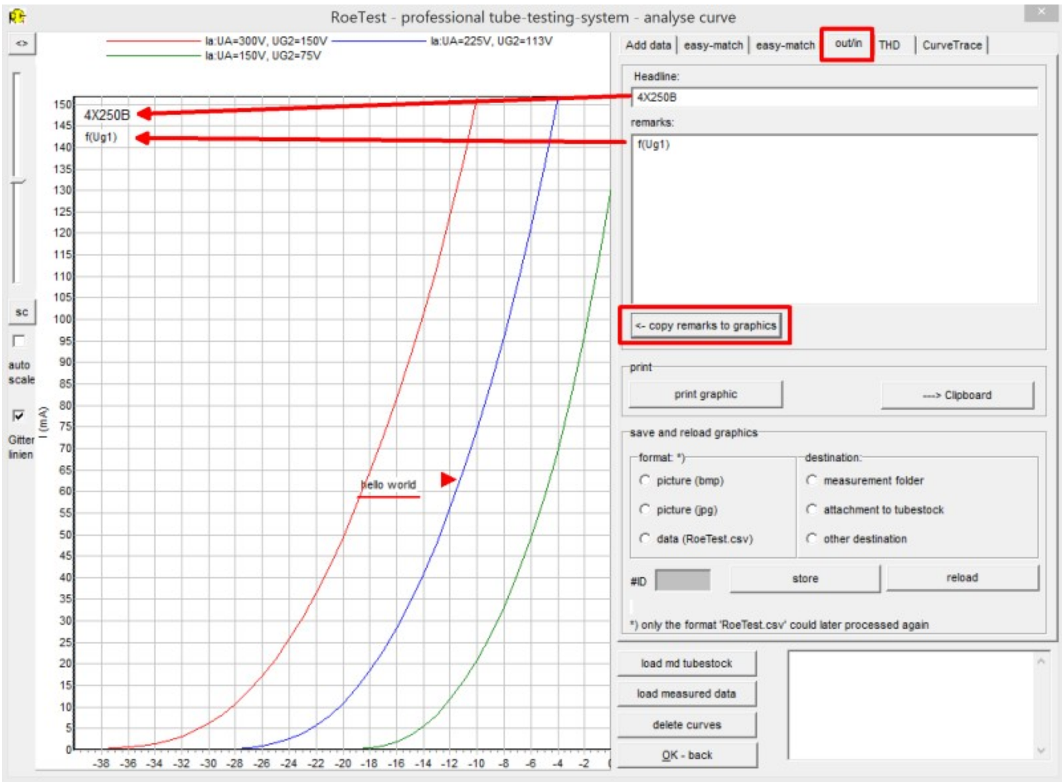
Clicking on a painting element in the first column will erase this element. All data can be changed manually, e.g. x- and y-position, the text, text size, font, line width, size of the triangle and colors.

Example:



Note: First load the characteristic curves and scale them. After that position the painting elements. The scaling should not be changed after painting elements have been drawn. Changing the scaling after elements have been painted will lead to incorrect positions of the painted elements.

With the button '<-copy remarks to graphics' you can embed the title and comments as painting elements into the graphics:



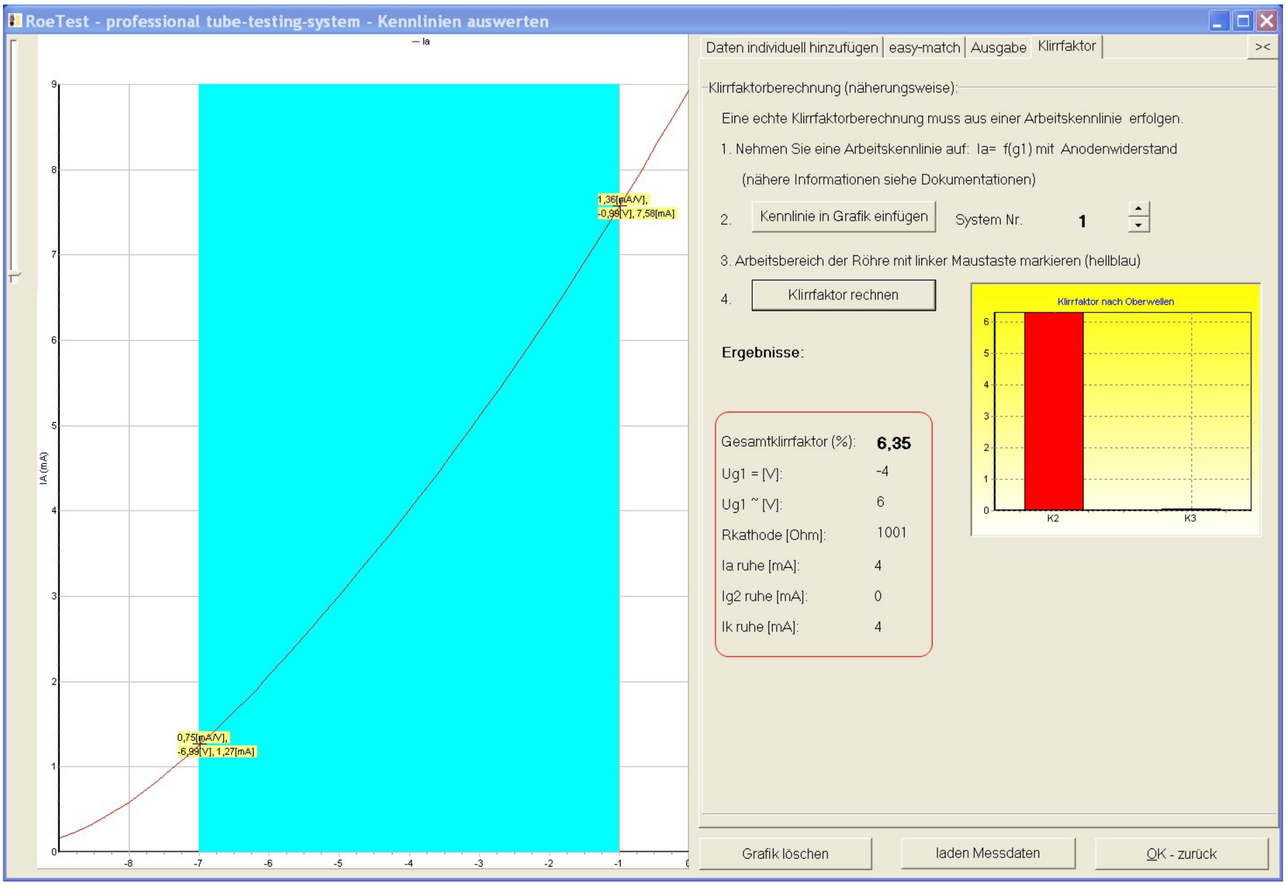
g) Calculation of the distortion factor and of an amplifier circuit:

In the same window the distortion factor for a specific control range can be calculated.

A true distortion factor calculation is only possible from a **working characteristic curve** (dynamic characteristic). A working characteristic curve is defined if a tube is operated with a specified load resistance in a given circuit. First the working characteristic curve must be recorded. How to do this is shown in the next example. More information regarding working characteristic curves are available in a separate hint.

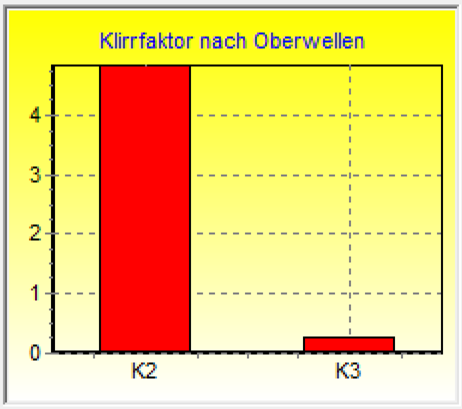
Using the button (see item 2.) the previously recorded characteristic curve will be copied to the analyzing graphics window.

The control range is selected by dragging the mouse with left button down over the blue marked region and then pressing the button <approximating THT> (german>Klirrfaktor rechnen>). Representation of the distortion factor is in percent and as graphical bars (harmonics).
The calculation of the distortion factor is highly dependent on the quality of the measured characteristic curve. Even small bends result in an increased distortion factor. The result should be taken as a 'hint'. The calculation is only an approximation.



In addition to the distortion factor some more data of the tube amplifier stage are calculated:

Ergebnisse:



Ug1 = [V]:	-12,15	Gesamtklirrfaktor [%]:	**5,09**
Ug1 ~ [V]:	13,7	Wechselstromleistung [W]:	**1,13**
Rkathode [Ohm]:	277	Anodenverlustleistung [W]:	4,18
Ia ruhe [mA]:	37,31		
Ig2 ruhe [mA]:	6,54	Verstärkung [µ]:	12,05
Ik ruhe [mA]:	43,85	dynamische Steilheit [mA/V]:	4,02

Along with the input data like the G1 bias voltage and the required cathode resistor value (if the G1 bias voltage is generated with that resistor) also the approximately expected output data, like distortion factor, AC power output, anode power dissipation, gain and dynamic transconductance will be calculated. The calculation is done using the fundamental frequency ignoring the harmonics. The results are purely theoretical. In real circuits there will be deviations, for example resulting from phase shifts etc.

You can play with the factors

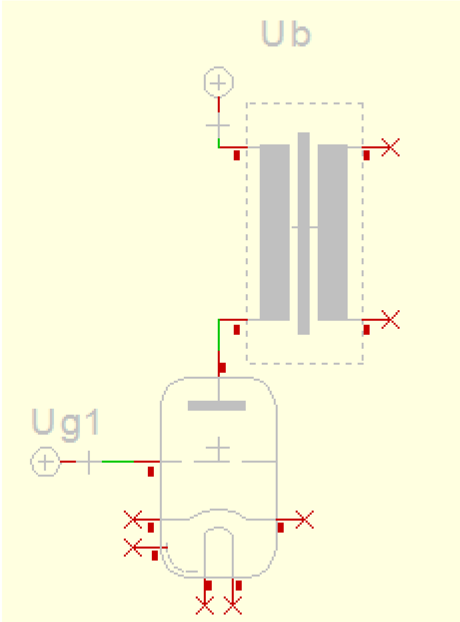
- control range
- different load resistors (-> different working characteristic curves)
- supply voltages (->different working characteristic curves)

and find optimal values for the amplifier stage in a very easy way.
You neither need much calculus nor generate circuits or models for simulation programs. Just record the working characteristic curve using a real resistor - the rest is only a matter of some mouse clicks!

This possibility should please the amplifier developing people.

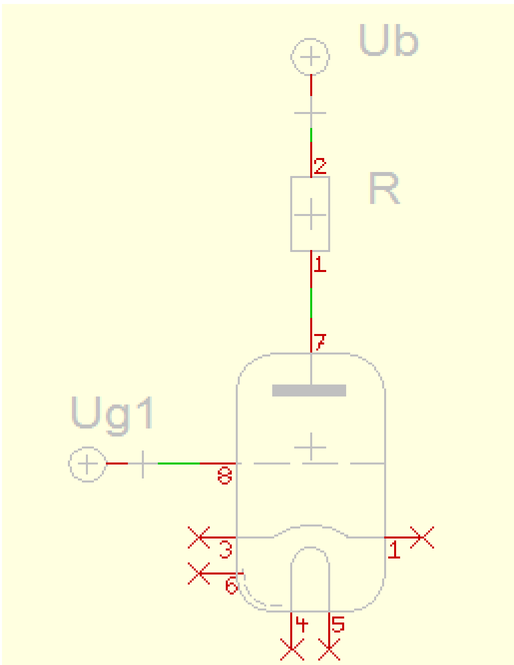
Example for recording of a working characteristic curve and the following calculation of distortion factor and amplifier:

As an example the well known EL84 is used in a standard circuit (screen grid not drawn, connected to +Ub):



The EL84 is capable of up to 12 Watt power dissipation and up to 300V anode voltage. For the output transformer we use an available type with a ratio of 1:26. Using an 8 ohms speaker results in a load resistance for the tube of 8 x 26² = 5408 ohms (rounded 5400). When calculating we assume that the transformer is ideal, i.e its DC resistance is 0 ohm. Without any modulation (steady state case) the anode voltage is equal to the supply voltage. With modulation the output voltage swings around the anode voltage, some times above, the other time below the supply voltage.

For the simulation we therefore use the following circuit:



We insert a resistor of 5400 ohms into the anode wire. To be able to simulate the "swinging around the supply voltage" the measuring voltage must be higher than the planned supply voltage. This must at least be the voltage that is dropped across the resistor in steady state. Inside the RoeTest there are up to 600V available, so this is no problem.

In this example we want to get as much power from the tube as possible; we will reach the power limit of the tube.

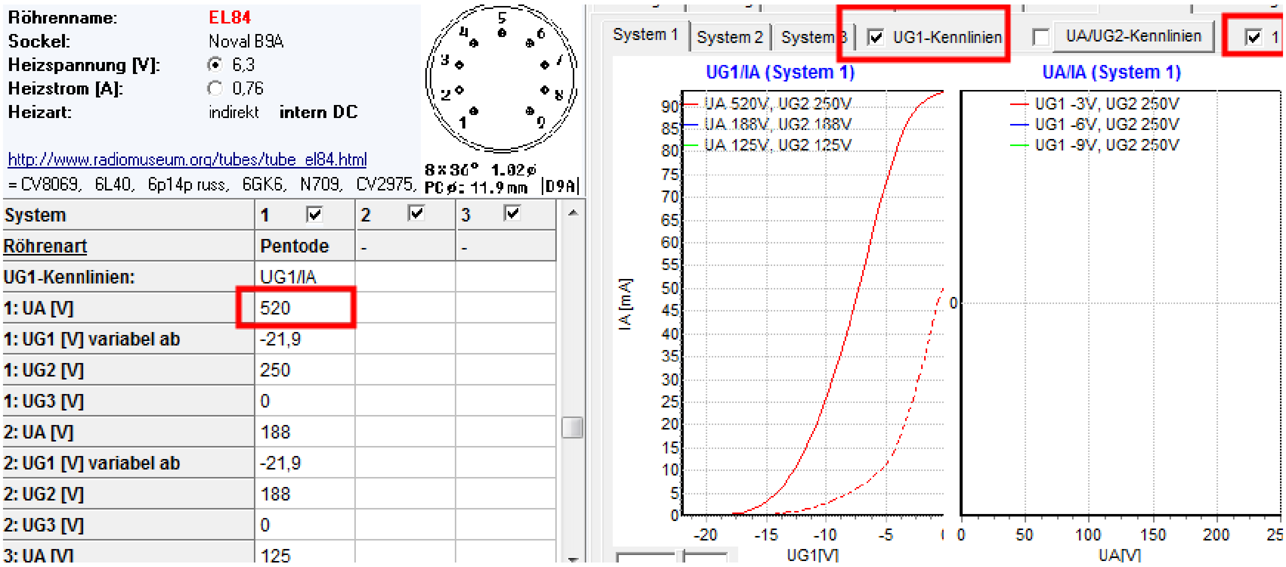
Lets define a quiescent current of about 45 mA. In this case there would be a voltage drop at the load resistance (5400 ohms) of 5400 Ohm x 0,045 A = 243 V.

When operating the amplifier at a supply voltage of 280V we would need for measuring about 520V (as the AC voltage swings around the supply voltage). If our assumptions are correct will be shown by the measure. Eventually we have to retry the measurement using different measuring voltages.

First we set the typical values temporaryly (not in the database!) to zero ('0') before starting the measurement, to avoid abort of the measuring process.

System	1	2	3
Röhrenart	Pentode	-	-
typische Werte:			
UA [V]	250,0	0,0	0,0
UG1 [V]	-7,30	0,00	0,00
UG2 [V]	250,0	0,0	0,0
UG3 [V]	0,0	0,0	0,0
IA [mA]	0	0,00	0,00
IG2 [mA]	0	0,00	0,00
S [mA/V]	11,00	0,00	0,00

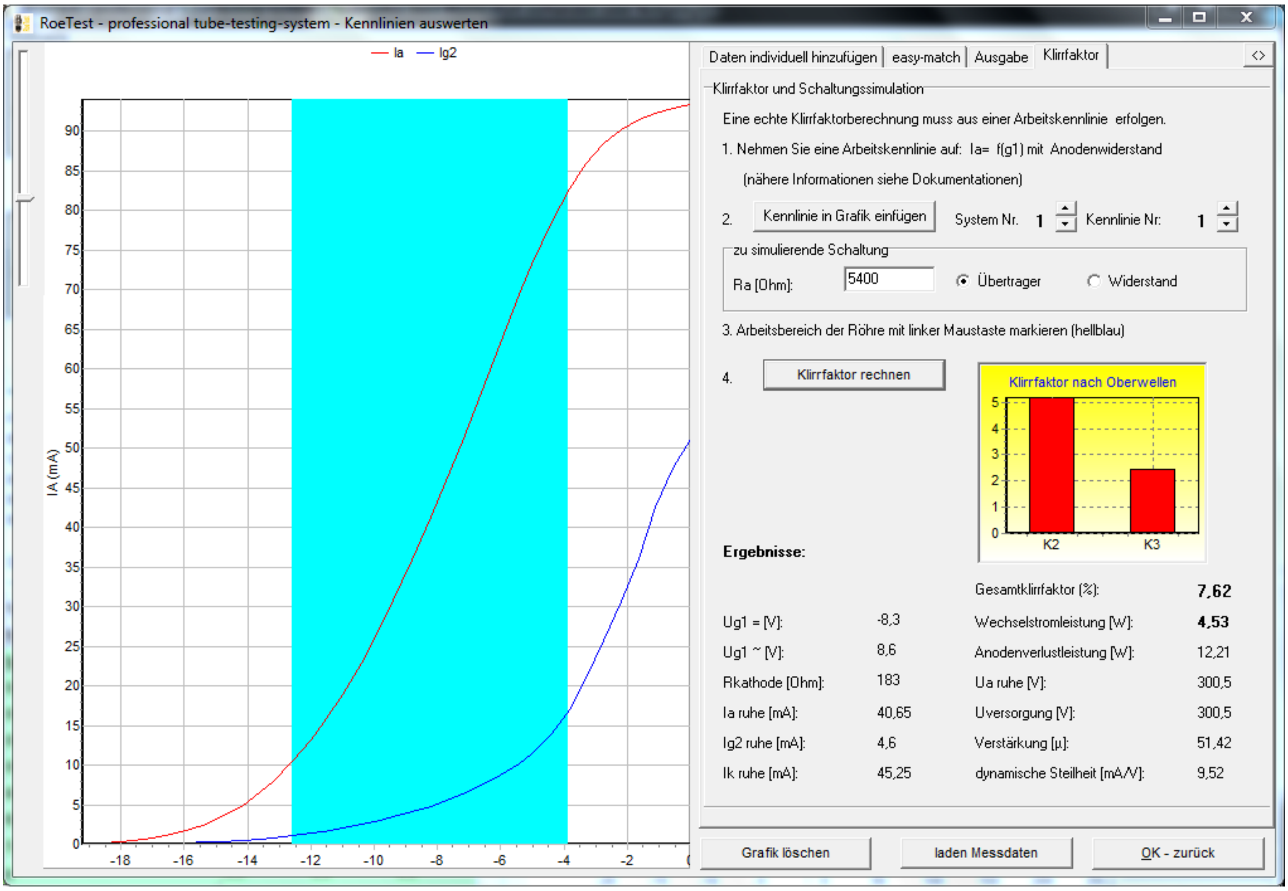
The resistor (5400 ohms, 11 watts) is inserted into the anode wire and a Ug1-characteristic curve is recorded. We adjust the voltage to 520V.



As a result we get the working characteristic curve of the EL84. Then we jump to the window "Kennlinien auswerten" and select the tab 'THD approximation'.

Now the following steps should be performed:

- Press button <add curve to graphic>
- Enter the resistor value of 5400 ohms and select "transformer"
- Drag mouse over the characteristic curve and select the control range (straight part of the working characteristic curve)
- Press button <approximating THD>



Result: At a distortion factor of ca. 7.6% the power output is approximately 4.5 watts. The supply voltage (= anode voltage) in steady state is 300V resulting in an anode power dissipation of somewhat slightly above 12 watts. Now you can play with the control range and do a new calculation. It can be useful to start a new measure with a slightly lower measuring voltage as we are already at the power limit of the tube. We could also play with different load resistors (for other transformers). To do this just start recording a new working characteristic curve with the appropriate resistor in place.

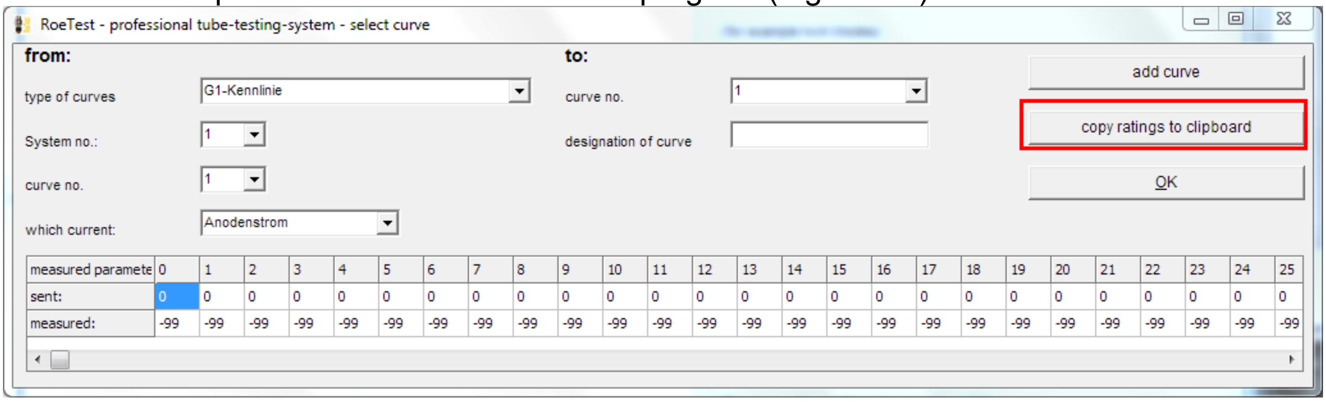
The EL84 is a popular audio tube for which there are ample amplifier designs available. The afore mentioned calculation possibilities are more interesting when using tubes that have not been used in the audio range before.

A further note: The calculations are only approximate. Real transformers and circuits can depart from the theoretical values. Also the calculation of power only uses the fundamental frequency. Further on a negative feedback that could reduce the distortion factor has not been considered. There will be no way to get around doing measurements in 'real' circuits. The possibilities that the RoeTest offers can nevertheless help to get faster to an achieved goal.

h) import,export, printing:

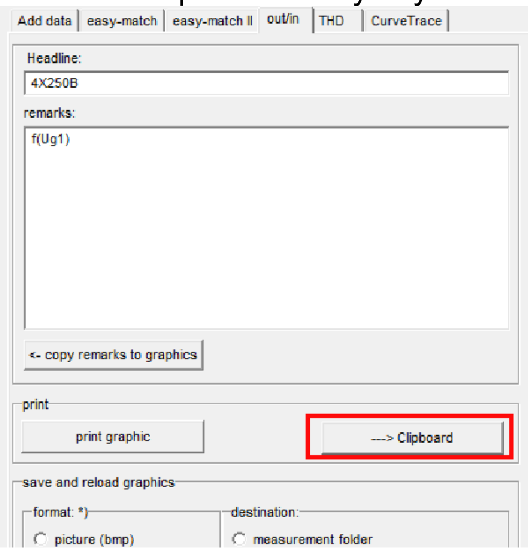
1. Value table

This table can be exported to the Windows clipboard with the following button and then be imported into a table calculation program (e.g. Excel).



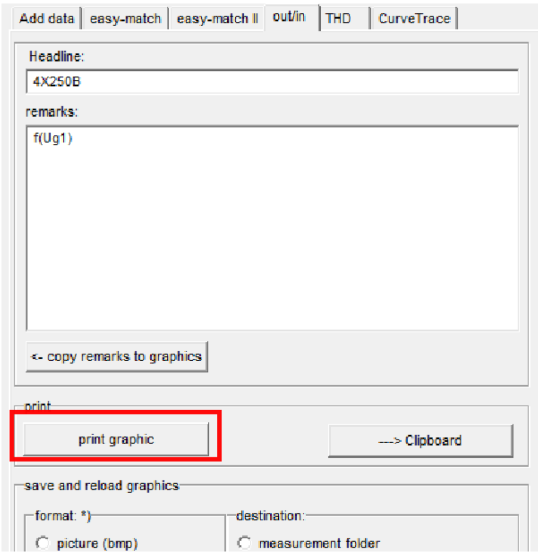
2. graphic to Clipboard

The graphics can be copied to the Windows clipboard with the following button and then be processed by any Windows program (e.g. MS-Paint or an editor)

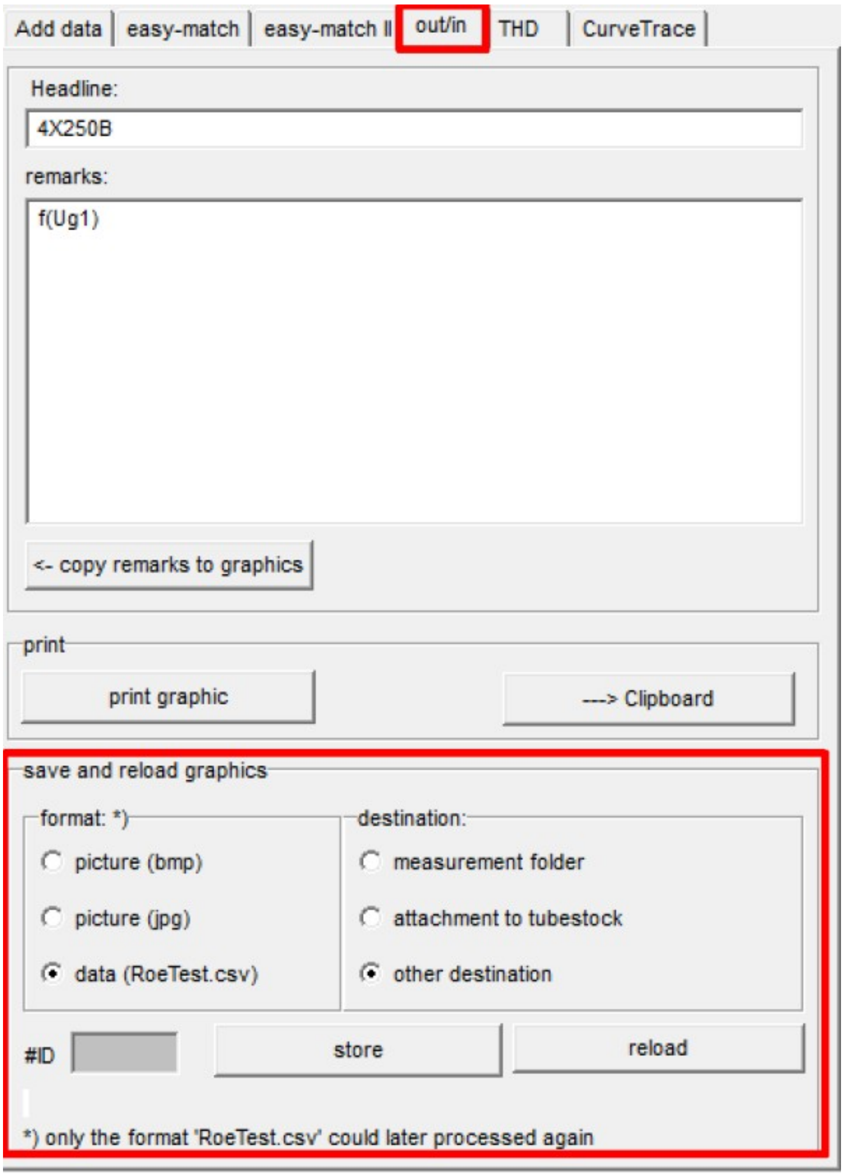


3. Printing

Using the above mask a caption line and comment text may be added and printed to any connected printer. If there is a 'virtual' pdf-printer installed, you can also print to a PDF file.



4. Importing and Exporting the Graphics (save and reload)



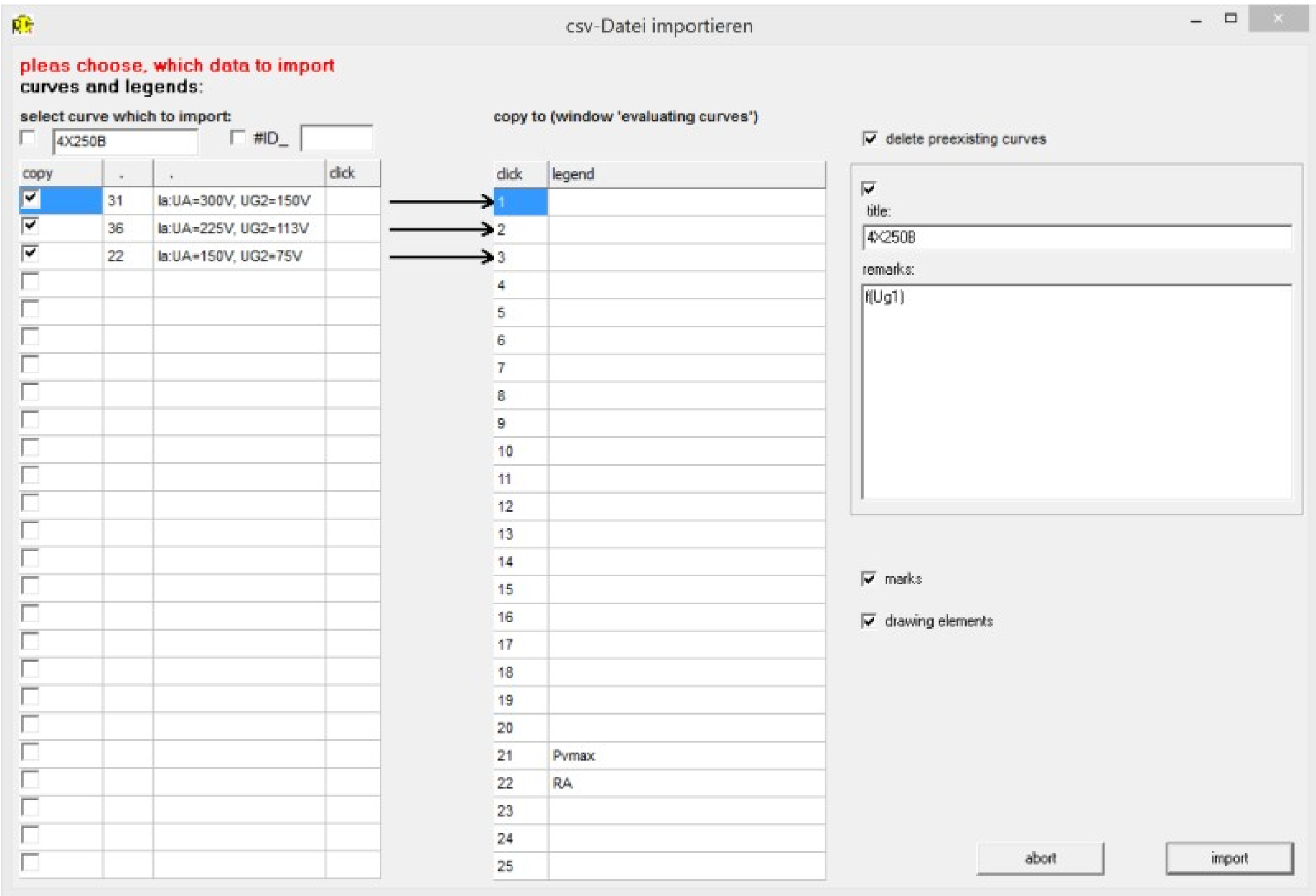
Left column: select the graphics format type (bmp, jpg or RoeTest.csv)
Right column: select the storage location, either measurement data folder, attachment to the tube stock database (in this case an #ID must be specified) or another storage location (the storage location will be saved for the next time).

Note:

- When you save the graphics as image format (bmp, jpg) they cannot be edited later. The images then can only be loaded as background graphics for viewing.
- When you save the graphics as '*_RoeTest.csv' format type then the graphics can be edited later. This is due to the fact that this format type stores all elements as single elements. The data may also be used in a spreadsheet calculation (e.g. Excel). Double clicking on a '*_RoeTest.csv' element in the tube stock database will open that file in roetest.exe

Loading a '*_RoeTest.csv' format file:

the following intermediate dialog will be opened:



You decide what elements will be reloaded (which curves at which position, title, comments, markers and drawing elements). You can also choose if the present graphics window shall be erased before reloading or if the existing data in the graphics window will be preserved. In this way you can compare curves from various files.

i) easy-match

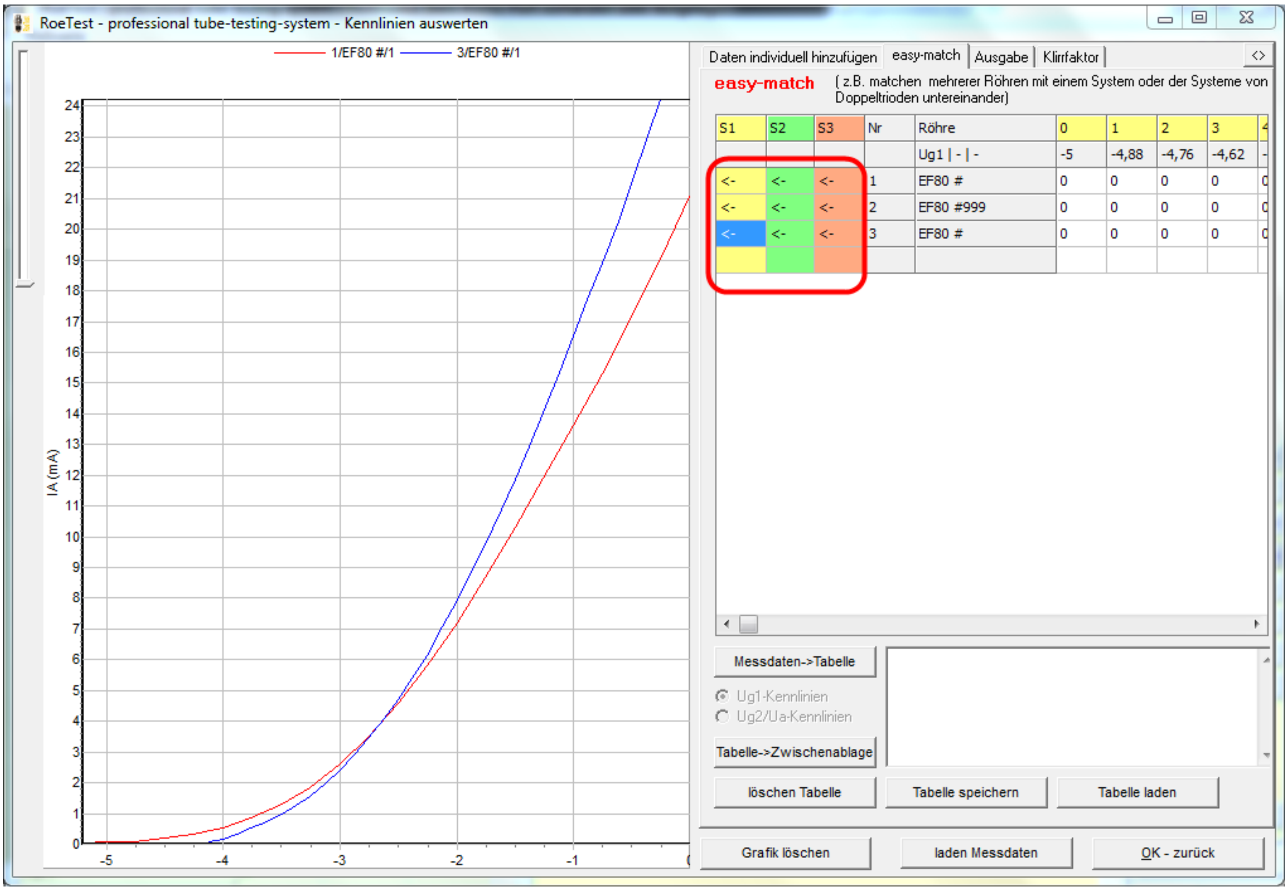
As already stated above it is best to match tubes by comparing their characteristic curves. Just superimpose the curves of different types and compare them.

To ease the task of comparing many tubes you can setup batch processing (see there) to store the measured characteristic curves to the easy-match table. You then only need to click (mouse left click, see read area in the picture below) on a table entry to compare the different characteristic curves – indeed very easy. You can show up to 20 curves. You can also remove the last curves with mouse right click to the table.

Note: When matching data, make sure to compare tubes of the same type and data that were recorded using the same parameters!

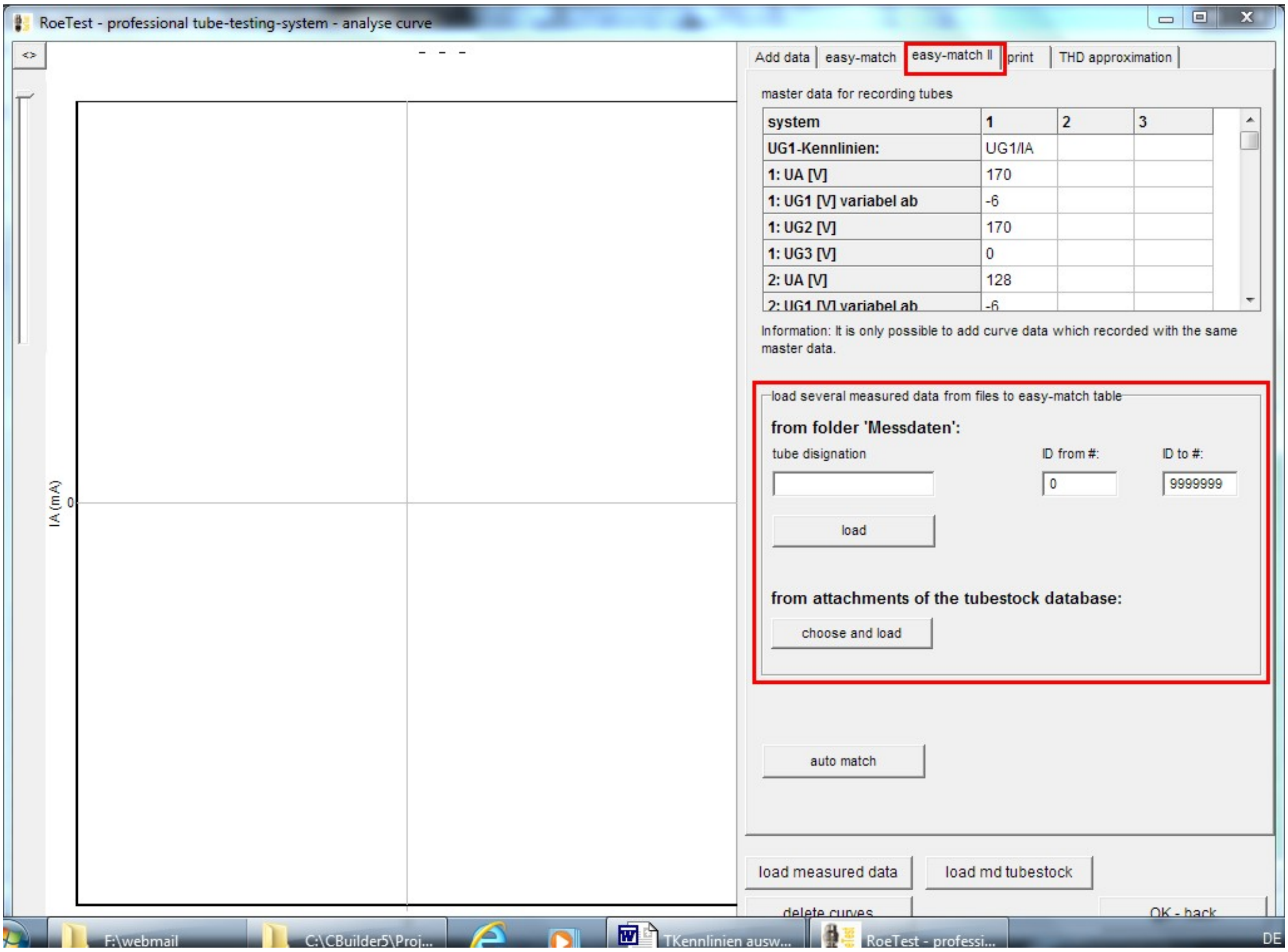
For that reason the system remembers the measured data of the first tube in the table. If another measure data set is added to the table the software checks if the characteristic curve has been measured using the same parameter set. I this false then the curve are not added and a message displayed 'error: tube curve recorded with other master data'

For comparing characteristic curves you only need a single curve per tube (system). To unify measuring practices I suggest to use a f(Ug1) characteristic curve.



The table is automatically saved on program exit and will be reloaded when the program is restarted. You can also store the table with a name of your choice and reload it.

k) easy-match II



At the upper right you see the underlying measure data for the tubes.

The red framed area is used to store multiple measure data to the easy-match table in one step.

You can select where to load the measured data from (usually the place where you stored them before):

1. from the measure data directory. This requires specifying the starting letters of the tube (file name of stored measure data) and the ID# (from-to)
2. from the appendix of the stock data base (tubestock.dbf). There is no limit for

the number of tubes. Theoretically you could compare thousands of tubes (same tube type and same measuring conditions required).

The button <**Auto-Match**> at the moment only does a simple sort of the tube data. Matching has to be done as already stated by comparing the characteristic curves in the analyzer window.

Note: It is planned to upgrade the system with a true automatic matching function in the future (calculation of least difference of the characteristic curves).