Testing Tubes with very high Conductance using a Cathode Resistor with the D3a as Example

Attention: From software V11.0.10.0 the connection of the cathode resistor changes!

Problems when measuring these Tubes:

The D3A is a frame grid tube with a very high conductance. It was used by Deutsche Post.

Due to the pentode's very high conductivity of 35 (30-40) mA/V (even higher when used in triode mode) there are the following problems:

- Tendency to oscillate: The testing device must be capable of handling the high conductivity and be able to suppress tube oscillations (no problem with the RoeTest when built with short wires and socket boxes containing only one socket according to my advice)

- A tiny change of the grid voltage results in a very high change of the plate current. Although the tubes are manufactured with tight tolerances small deviations from the average characteristic curve have significant effects. So standard tube measuring is of little value.

Data sheet of the D3a:

Due to the aforementioned reason the data sheet of the D3a specifies another measuring method, the use of a cathode resistor. An excerpt from the data sheet (Siemens):

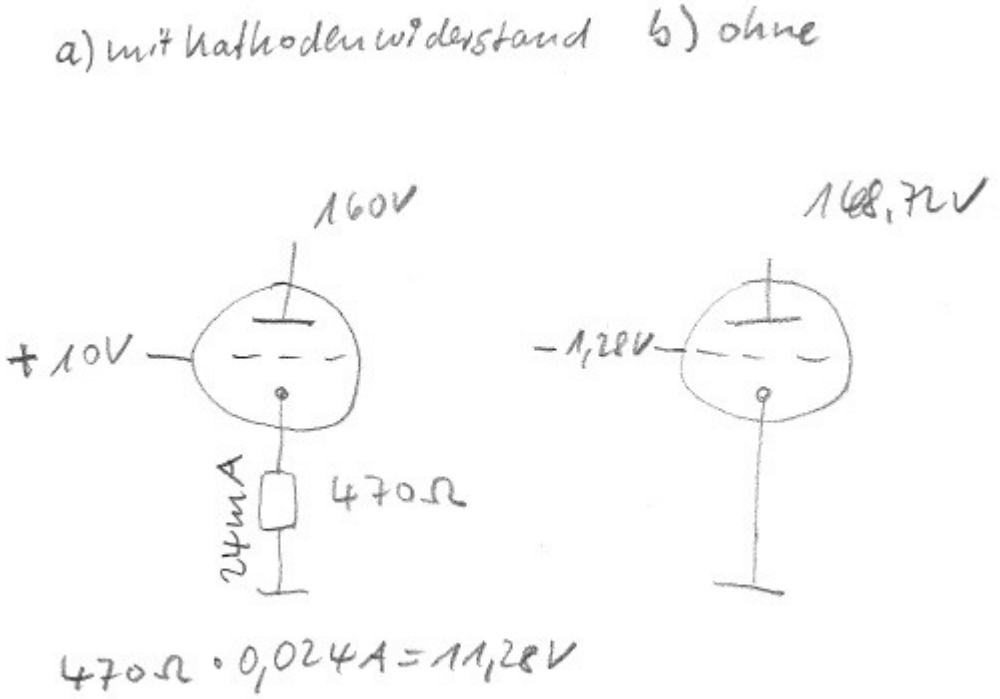
Kenndaten

		min.	nom.	max.	
U_{ba}	=		190		V
U_{g3}	=		0		V
U_{bg2}	=		160		V
$+U_{bg1}$	=		10		V
R_k	=		400		Ω
I_a	=	21	22	23	mA
I_{g2}	=	5,4	6	6,6	mA
S	=	30	35	40	mA/V
μ_{g2g1}	≈		80		
R_i	=		120		kΩ
R_{aq}	=		150		Ω
R_{el} (100 MHz)	=		1		kΩ 1)
S/C	=		2,9		mA/VpF
$S/2\pi C_{ges}$	=		230		MHz 2)
F	=		7		dB 3)
$-I_g$	≤			0,3	µA

Triodenschaltung (g2 an a, g3 an k)

U_{ba}	=		160		V
U_{g3}	=		0		V
$+U_{bg1}$	=		10		V
R_k	=		470		Ω
I_a	=		24		mA
S	=		41		mA/V
µ	≈		77		
R_i	=		1,9		kΩ
R_{aq}	=		65		Ω

According to the data sheet a cathode resistor of 400 Ohm has to be used when measuring as a pentode and a resistor of 470 Ohm when measuring as a triode. In the following consideration the circuit as a triode (plate and screen grid connected) is used for easier presentation:



According to the data sheet the average voltage drop at the cathode resistor is 11,28V. Feeding +10V to the grid results in the following effective voltages at the tube:
Plate-Cathode voltage: 148,72V (160-11,28)
Grid-Cathode voltage: -1,28 V (10-11,28)

So also in this case the tube is still driven with negative grid bias. The cathode resistor causes a large negative feedback. The tube self stabilizes its working point. Conductivity is greatly reduced.

The data sheet specifies for this case that the tube is within specifications when the plate current is within +/- 1 mA of the nominal value. The test card of the Grundig 55a is even less restrictive and allows a tolerance of the plate current of +/- 10%.

In the following the test card of the Grundig 55a tube tester (a tube tester custom-made for Deutsche Post) and the Neuberger test card:

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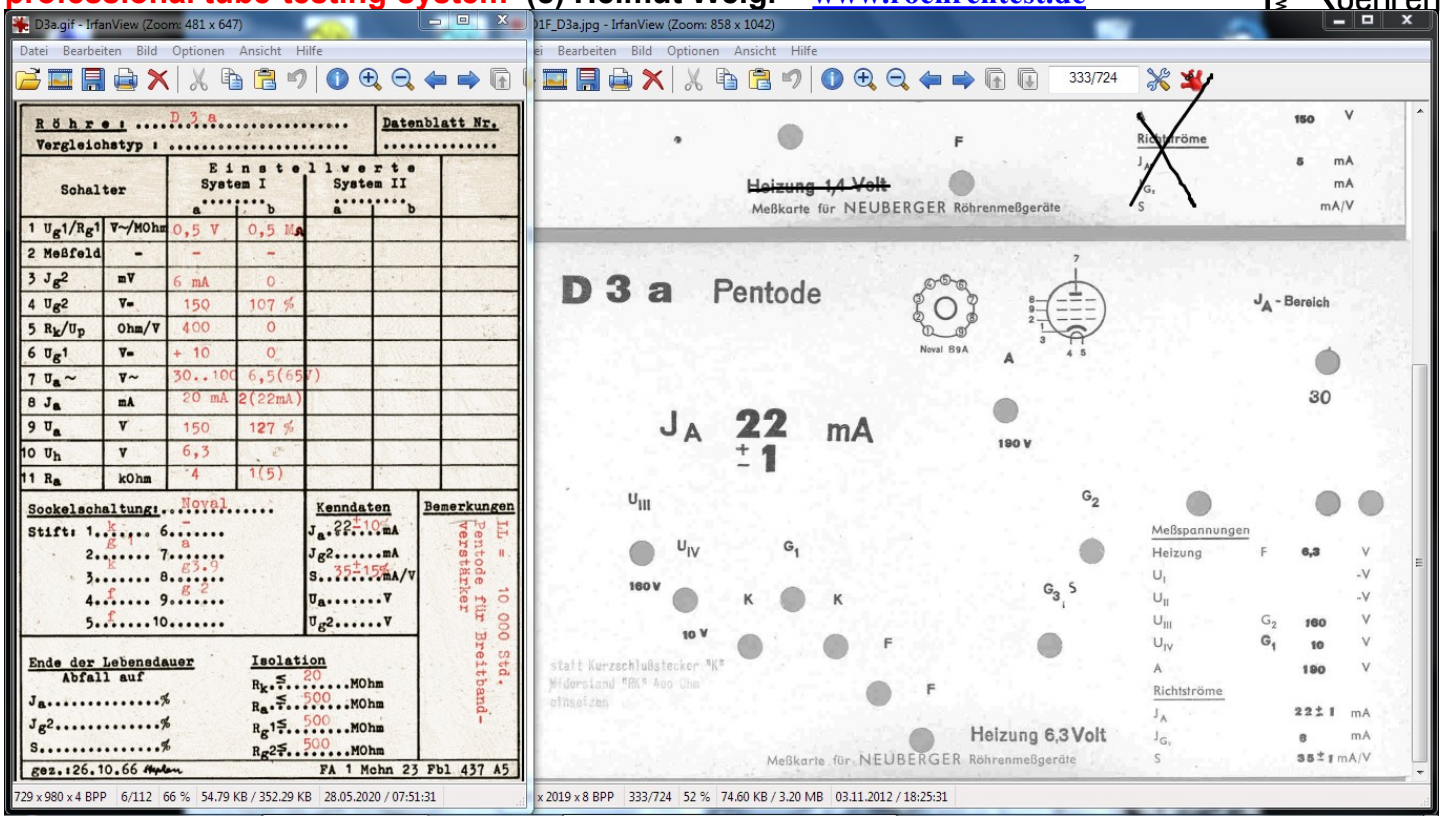

Both tube testers require the use of a cathode resistor (due to the reasons mentioned above).

Note: Static measuring the conductivity or characteristic curve recording with a cathode resistor is not meaningful (with the D3a the cathode resistor reduces conductivity to about 2 mA/V). Due to this reason **two measurement cycles** are done with the RoeTest, first the plate current with the cathode resistor and second further static measurements (e.g. conductivity) without cathode resistor.

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RoeTest Measurement with Cathode Resistor:

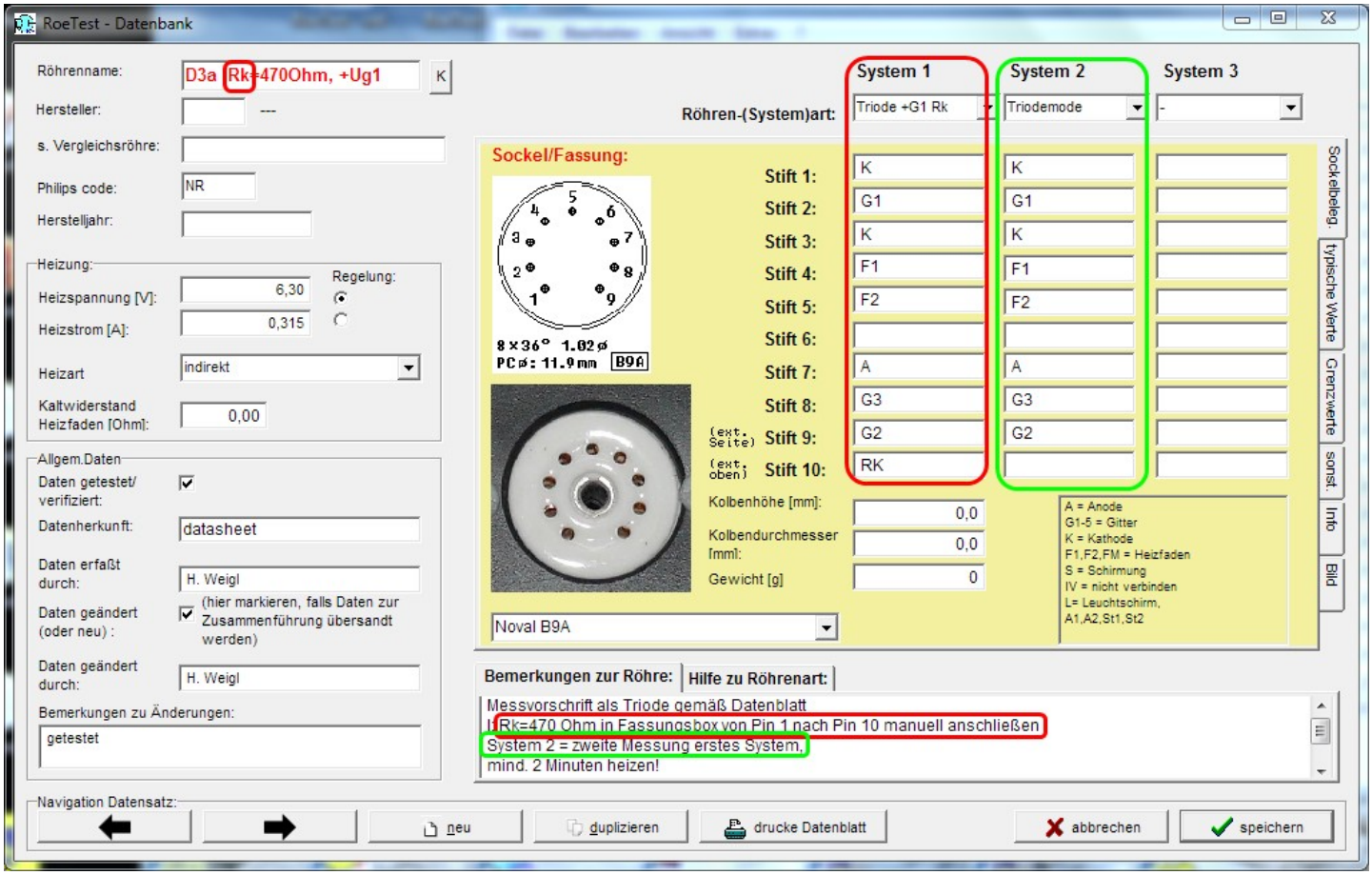
The test with a cathode resistor with the RoeTest requires the following conditions:

- Hardware Version >= V9
- Software Version >= V 10.3.1.0

Measurement shall be done conveniently. When all required data have been specified all measurements are done automatically, started with the button <stat.Messung> (static measurement).

1. The RoeTest provides, besides the heater voltage, two positive voltage sources: The A-Card and the G2-Card. The G2-Card is used for the positive grid voltage of +10V. The A-Card remains for the other positive voltages. The tube's plate and screen grid are connected for the measurement. Measurement is done in triode mode as described in the data sheet.
2. A 470 Ohm/0,6W cathode resistor has to be connected manually. This resistor should be as accurate as possible (either measure from 1% type resistors or better use a 0,1% type resistor).
   The resistor has to be placed between **jack 10 and ground**.

3. Data set for the D3a: For testing this type of tube a specific data set was defined:



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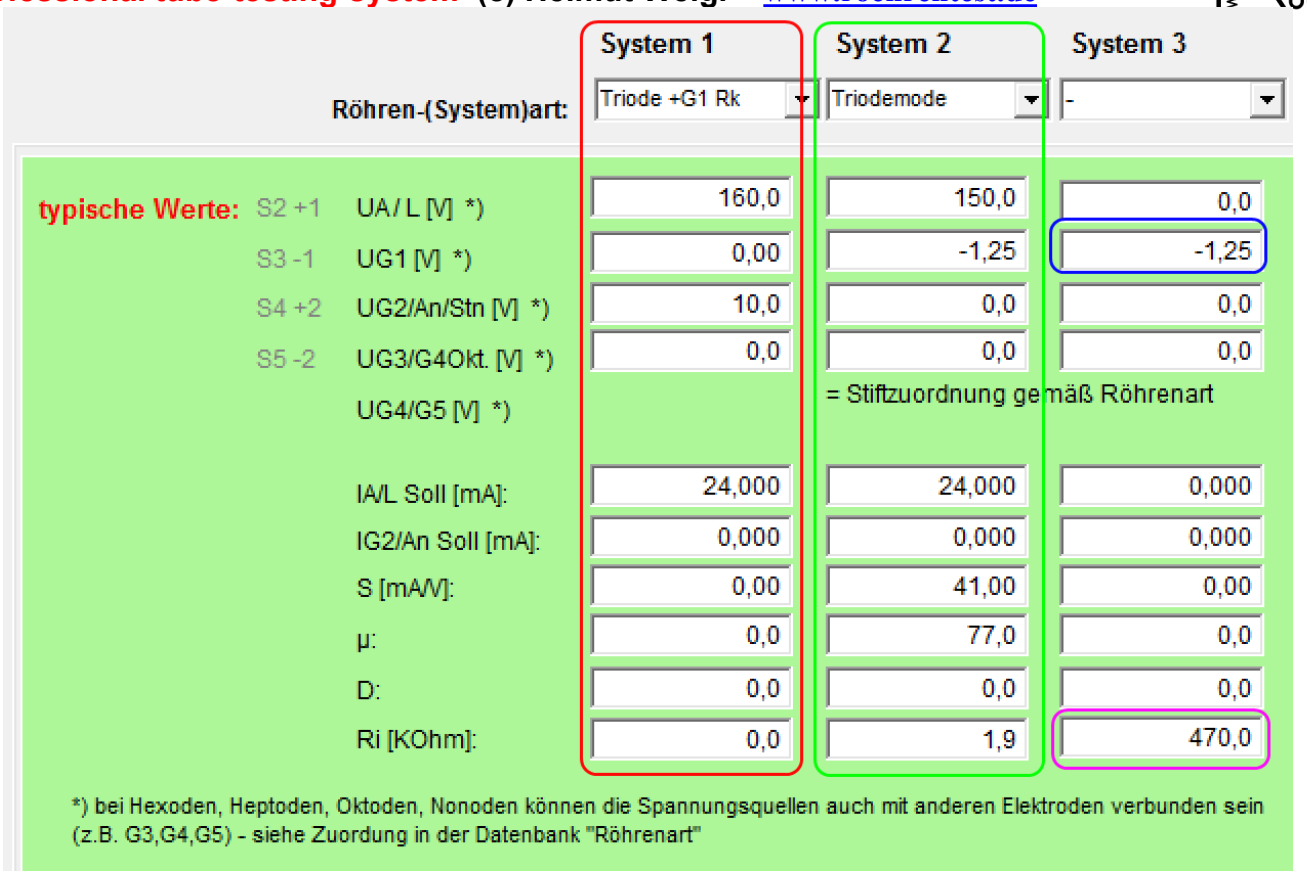


			System 1	System 2	System 3
		Röhren-(System)art:	Triode +G1 Rk	Triodemode	-
typische Werte:	S2 +1	UA / L [V] *)	160,0	150,0	0,0
	S3 -1	UG1 [V] *)	0,00	-1,25	-1,25
	S4 +2	UG2/An/Stn [V] *)	10,0	0,0	0,0
	S5 -2	UG3/G4Okt. [V] *)	0,0	0,0	0,0
		UG4/G5 [V] *)		= Stiftzuordnung gemäß Röhrenart	
		IA/L Soll [mA]:	24,000	24,000	0,000
		IG2/An Soll [mA]:	0,000	0,000	0,000
		S [mA/V]:	0,00	41,00	0,00
		µ:	0,0	77,0	0,0
		D:	0,0	0,0	0,0
		Ri [KOhm]:	0,0	1,9	470,0

*) bei Hexoden, Heptoden, Oktoden, Nonoden können die Spannungsquellen auch mit anderen Elektroden verbunden sein (z.B. G3,G4,G5) - siehe Zuordung in der Datenbank "Röhrenart"

First Measurement Cycle:

In the data set's column System 1 the test parameters with cathode resistor are defined(typical values according to the data sheet). Here the plate current is measured with cathode resistor. The defined tube type „**Triode +G1 Rk**“ ensures that the cathode resistor „RK“ connected to Pin 10 will be switched to ground instead of the „K“ connections. The value of the cathode resistor has to be entered in the column for System 3 in the field Ri in Ohm (not kOhm).

Second Measurement Cycle:

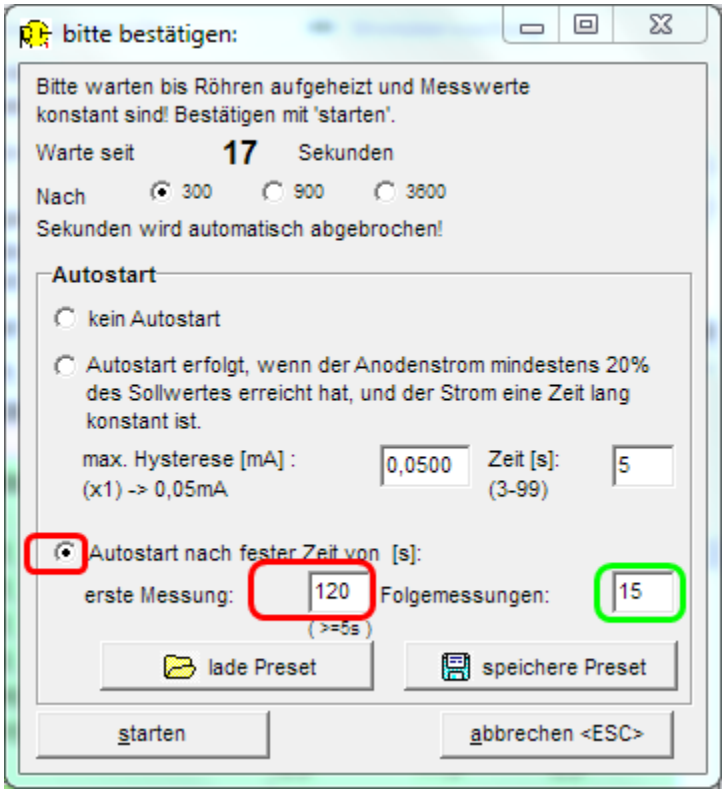
The column System 2 is used for the second measurements (principally the data fields for a second tube system can also be used for the same tube system but for different measurement tasks). Here the tube measurements are done without cathode resistor. The tube's „K“ connections are switched to GND. Connector „RK“ is not switched.

Ug1 for Vacuum Measurement

When performing Vacuum measurements Ug1 must be constant to ensure comparability of the measured values. On the one hand Ug1 shall be small so that with weaker tubes grid current can still be measured. On the other hand measurement shall be done outside the tube's region where current begins to flow. Further on Ug1 must be sufficiently negative so that with good tubes there will not be a too large plate current. For the D3a I determined an optimum Ug1 of -1,25V. This value shall be specified in the column for "System 3". If no value is given there a standard value of -1,5V will be used for grid current measurement.

When pressing the button <**statische Messung**> (static measurement) the following happens: In a first measurement cycle the plate current with cathode resistor is measured. Additionally the estimated effective plate voltage and grid voltage are calculated and written to the green fields of the second system.

Important: Before starting the first measurement cycle you **should at least wait 2 minutes** (longer is better) until the tube is properly heated up and the automatic working point regulation with the cathode resistor has stabilized. You can specify the RoeTest Autostart for fixed time as follows:



After the first measurement a second measurement cycle is automatically started from the RoeTest.
Now the grid voltage is searched that will approximately yield the same plate current as found in the first measurement with cathode resistor. With that working point further static measurements are done (conductivity, inverse amplification factor, grid current etc.). After the static measurements have been done (and hence the working point has been found) characteristic curve recordings can be done. By the way, for the second measurements I defined another additional tube type „Triodemode“. With this type the pentode is measured in triode mode (plate and screen grid will both be connected to the A-Card).

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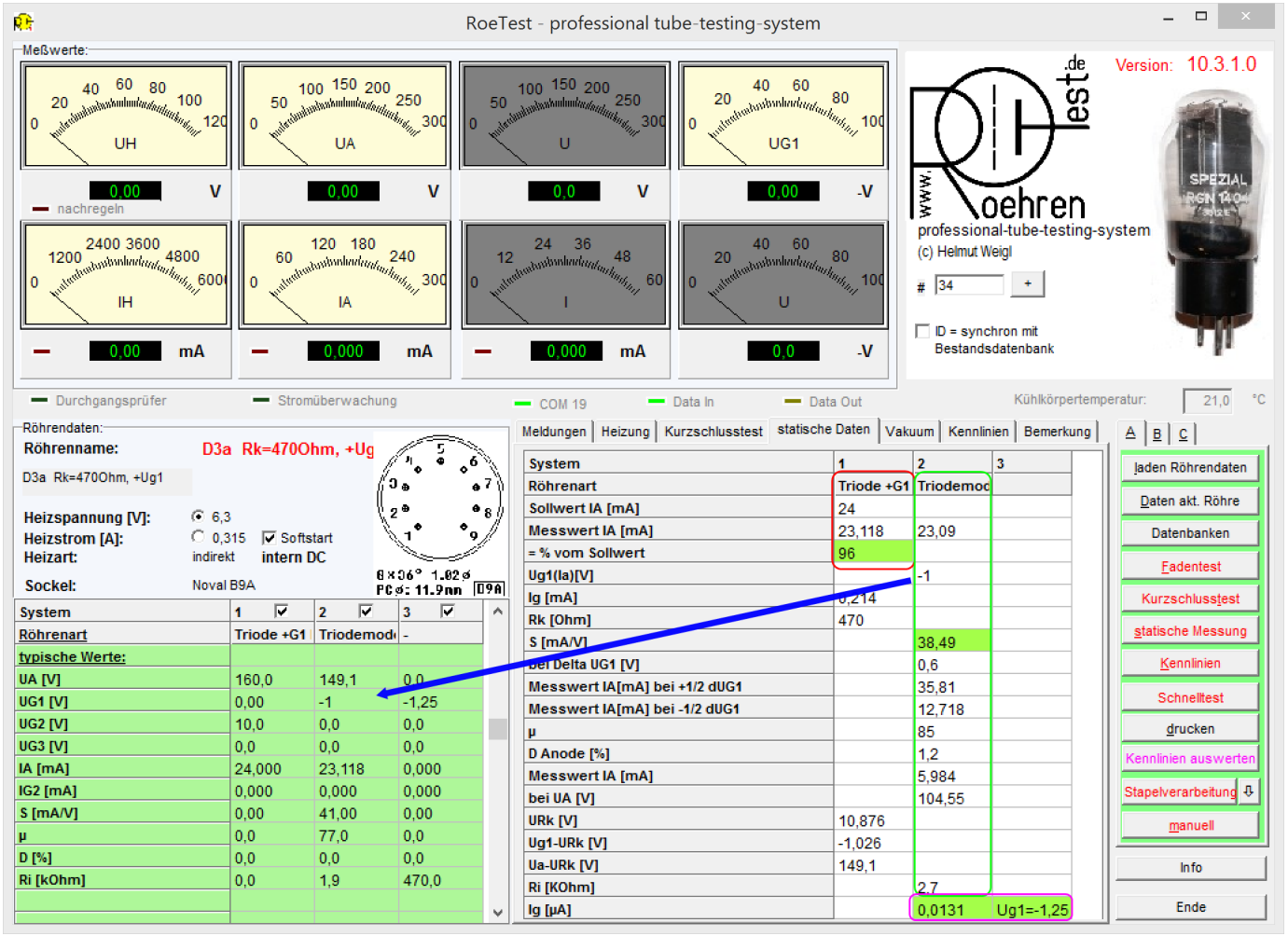
The measured values look like that:



System	1	2	3
Röhrenart	Triode +G1	Triodemod	-
typische Werte:			
UA [V]	160,0	149,1	0,0
UG1 [V]	0,00	-1	-1,25
UG2 [V]	10,0	0,0	0,0
UG3 [V]	0,0	0,0	0,0
IA [mA]	24,000	23,118	0,000
IG2 [mA]	0,000	0,000	0,000
S [mA/V]	0,00	41,00	0,00
µ	0,0	77,0	0,0
D [%]	0,0	0,0	0,0
Ri [kOhm]	0,0	1,9	470,0

System	1	2	3
Röhrenart	Triode +G1	Triodemod	
Sollwert IA [mA]	24		
Messwert IA [mA]	23,118	23,09	
= % vom Sollwert	96		
Ug1(Ia)[V]		-1	
Ig [mA]	0,214		
Rk [Ohm]	470		
S [mA/V]		38,49	
bei Delta UG1 [V]		0,6	
Messwert IA[mA] bei +1/2 dUG1		35,81	
Messwert IA[mA] bei -1/2 dUG1		12,718	
µ		85	
D Anode [%]		1,2	
Messwert IA [mA]		5,984	
bei UA [V]		104,55	
URk [V]	10,876		
Ug1-URk [V]	-1,026		
Ua-URk [V]	149,1		
Ri [KOhm]		2,7	
Ig [µA]		0,0131	Ug1=-1,25

red: First measurement cycle, plate current with cathode resistor 470 Ohm
green: Second measurement cycle, measuring of conductivity, inverse amplification factor, etc.
Blue: Approximation to the working point 23,008 mA (as the maximum resolution of the G1-Card is 0,025V , approximation to 23 mA can only be roughly done. Due to the large conductivity the current at a grid voltage of -1,000V would already be further away from the nominal value).
Grid current measurement at specified measuring condition (Ug1 = -1,25V).

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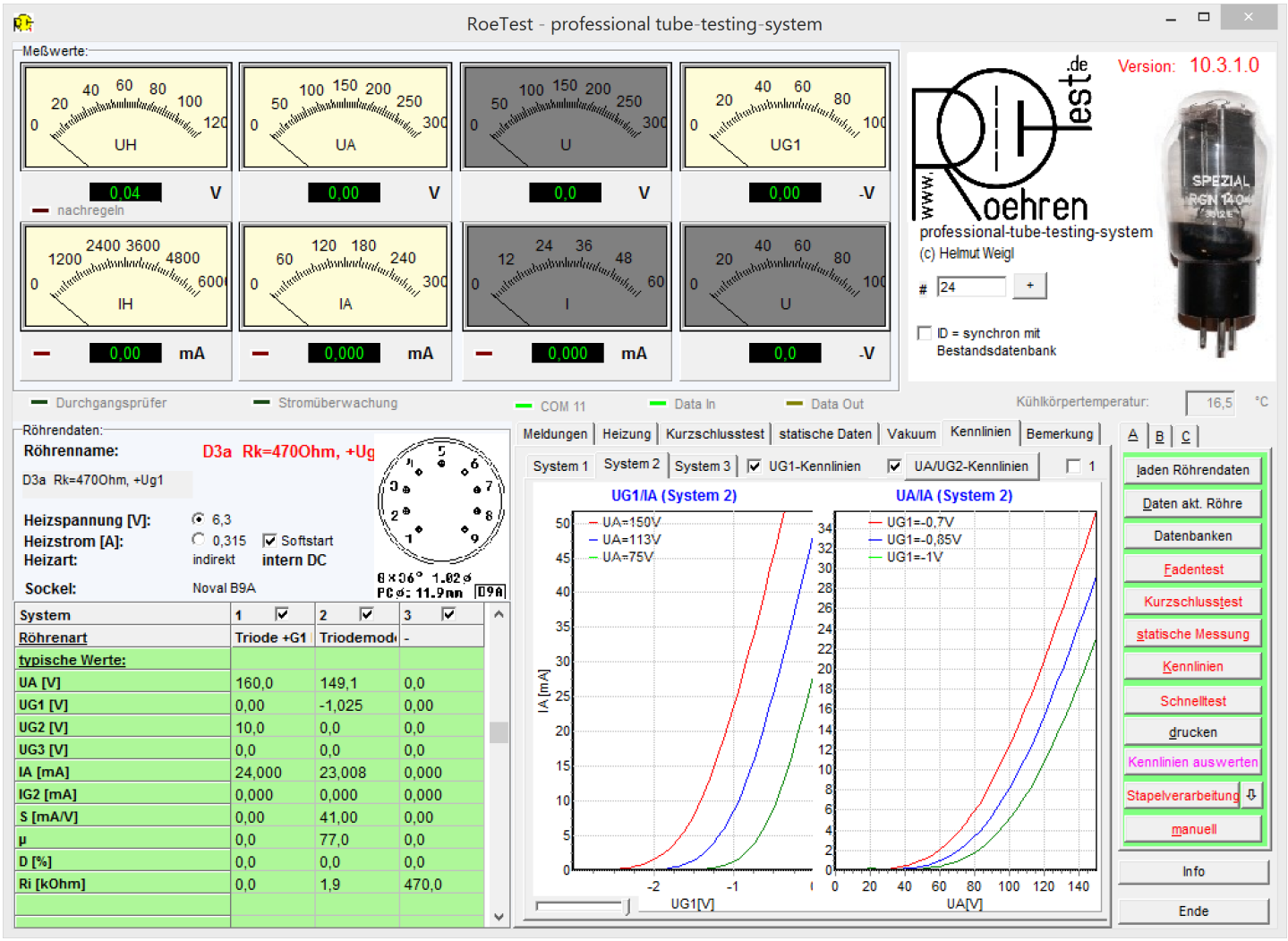
Characteristic curves can be recorded in the usual manner after the static measurements have been done (with the data measured from the second measurement cycle):



System	1	2	3
Röhrenart	Triode +G1	Triodemod	-
typische Werte:			
UA [V]	160,0	149,1	0,0
UG1 [V]	0,00	-1,025	0,00
UG2 [V]	10,0	0,0	0,0
UG3 [V]	0,0	0,0	0,0
IA [mA]	24,000	23,008	0,000
IG2 [mA]	0,000	0,000	0,000
S [mA/V]	0,00	41,00	0,00
µ	0,0	77,0	0,0
D [%]	0,0	0,0	0,0
Ri [kOhm]	0,0	1,9	470,0

Note: With the above given measuring method one complete data set is required for one tube system. For tubes with more systems additional full data sets per system are required.

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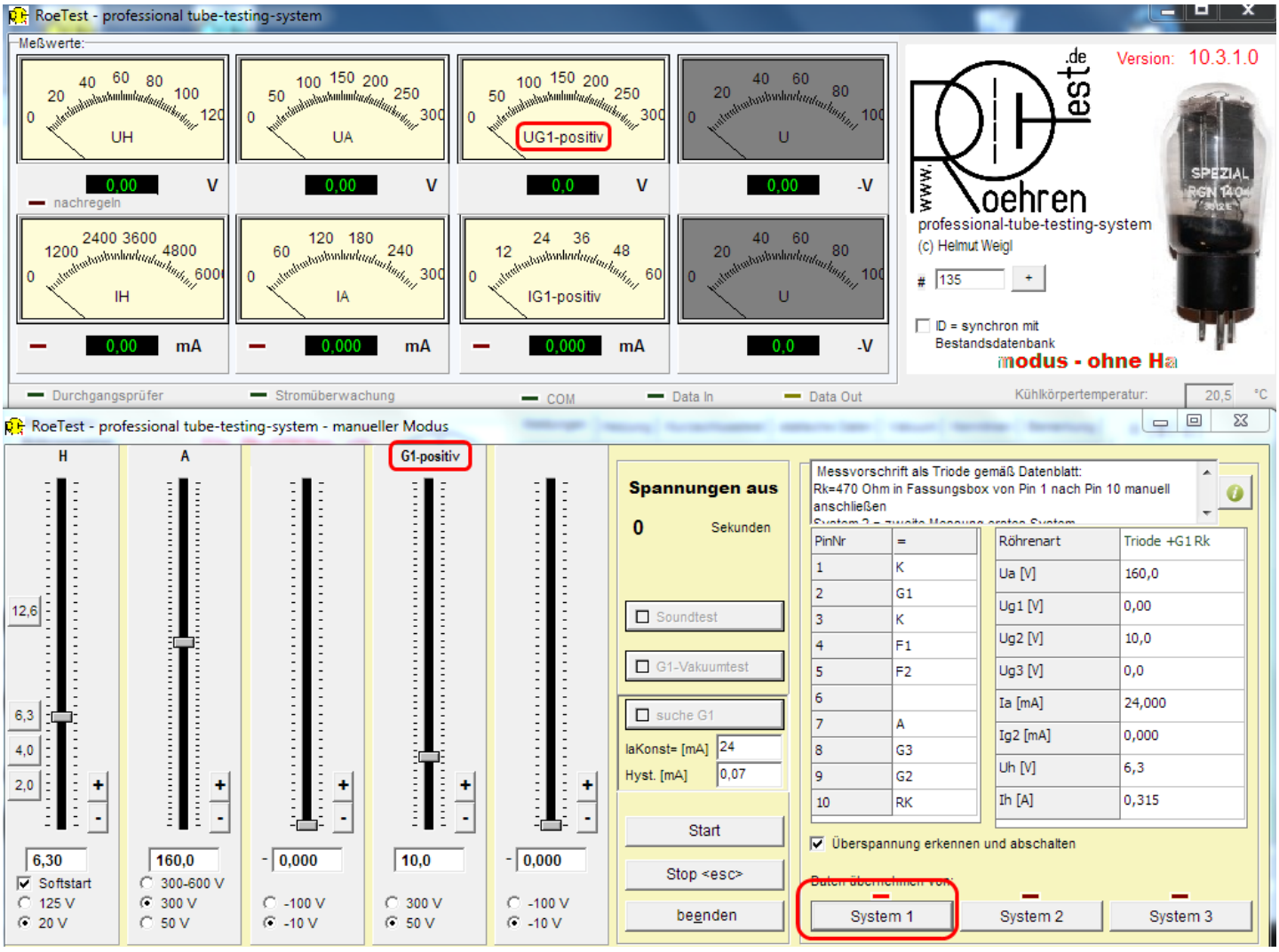
Manual Mode

With the same data set the tube can also be tested in manual mode. The data from System 1 may be used for measurements with cathode resistor, the data from System 2 for measurements without cathode resistor.



Effects affecting the Measurement Results caused by the RoeTest's inaccuracy

a) First measurement cycle with cathode resistor and positive grid voltage:

The measurement with cathode resistor requires a positive grid voltage that is supplied from the G2-Card. The G2-Card has a voltage resolution of 0,1 V. There is no alignment possible at the lower alignment point but only an approximation. Worst case the voltage can be off by ½ Bit of the desired voltage of +10V. The actual voltage might be between 9,95V and 10,05V.

Experimental measurement of a tube with cathode resistor, change of plate current depending on change of grid voltage (at working point):

Ug [V]	9,9	10	10,1
Ia [mA]	22,948	23,143	23,338

Therefore the current change resulting from one half bit inaccuracy is:

(23,338 - 22,948) (10,1-9,9) x 0,5 = 0,0975 mA max.

This is equivalent to a maximum deviation of 0,416 % from the nominal value of 24 mA.
The small G1-Deviation is the same with all tubes and can thus be neglected.

b) Second measurement cycle without cathode resistor and negative grid voltage:

The negative voltage is supplied from the G1-Card. This card has a voltage resolution of 0,025V and is adjustable both at the lower and the upper range end. Tracking is very precise.

Measurement is done without cathode resistor, thus with a very high tube conductance of about 40 mA/V. This conductance leads to a change of plate current per DAC step of 40 x 0,025 = 1 mA. At start of the second measurement cycle an approximation of the working point found from the first measurement cycle is tried. To achieve this the grid voltage is varied accordingly to give best possible approximation of the plate current from the first measurement. The G1-Card has an intrinsic inaccuracy of ½ Bit what corresponds to an approximation error of +/- 0,5mA of the plate current. Conductance, etc. is measured very close to the optimum working point. This should not lead to a significant deviation of the measurement results.

Conclusion: The measurement accuracy of the RoeTest is good for both the first and the second measurement cycle.

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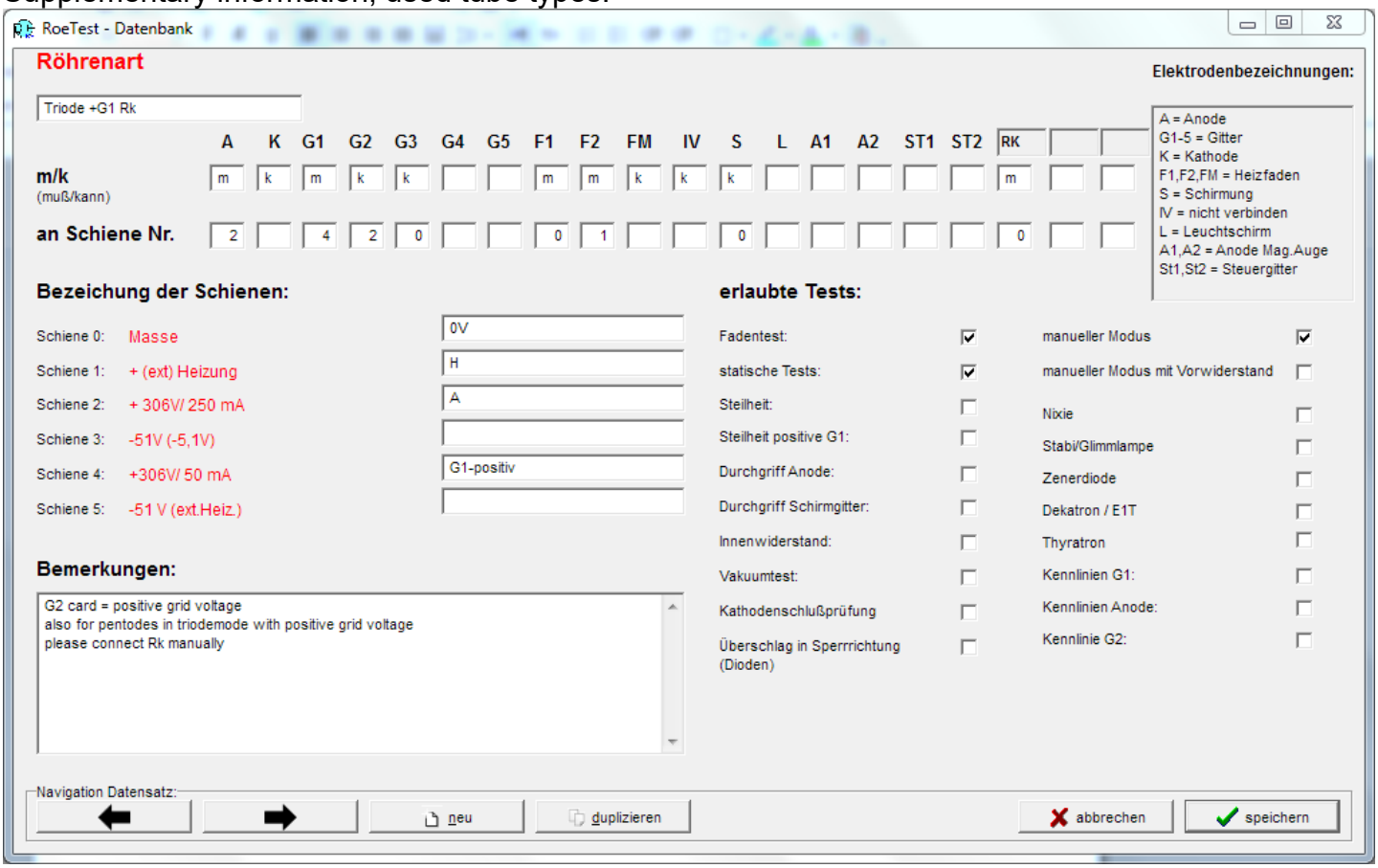
Supplementary information, used tube types:



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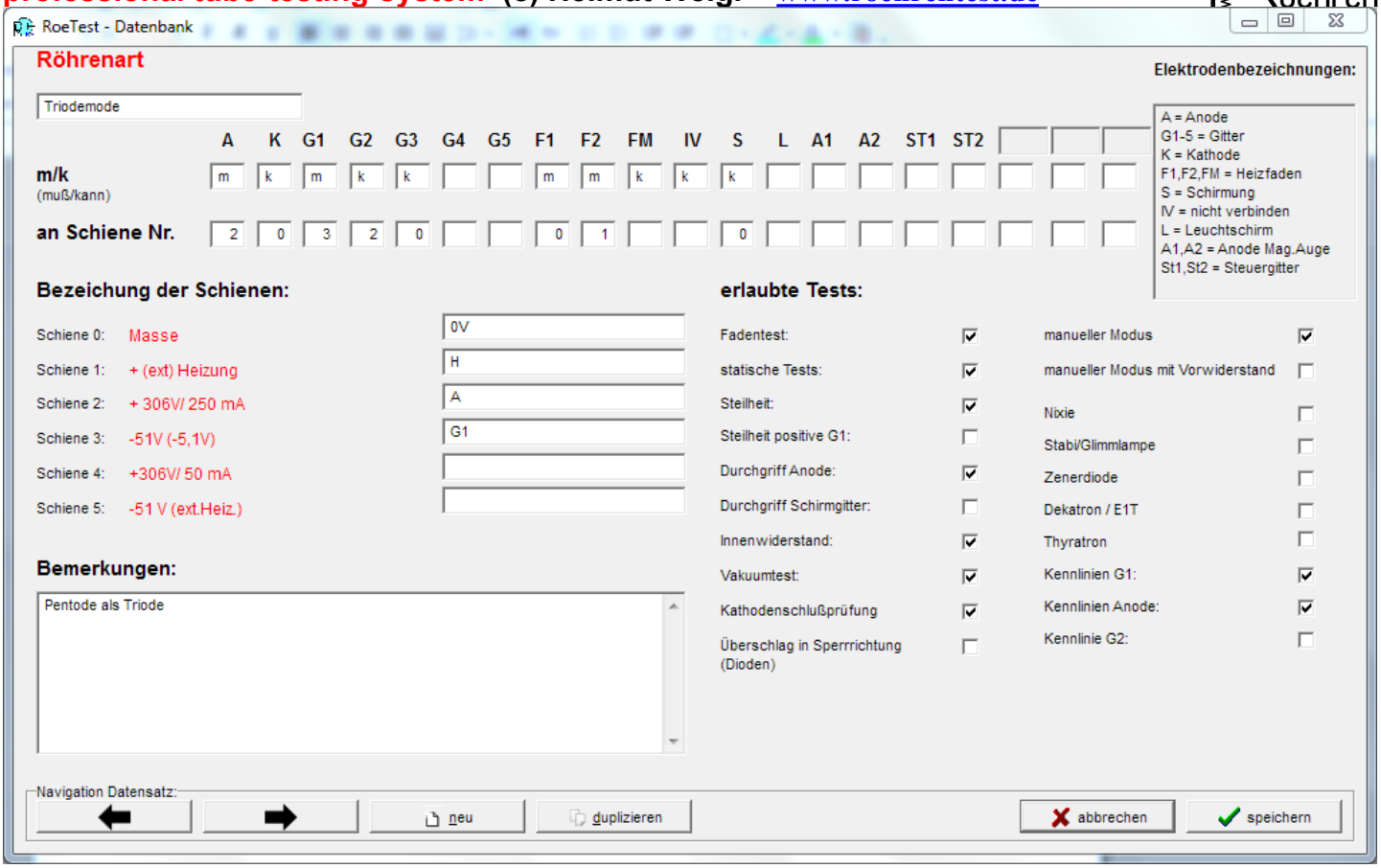

From software 10.5.2.0 there is also a tube type 'Pentode -G1 Rk' for tubes which require a negative grid voltage in addition to the cathode resistance.