SIT – Static Induction Transistor

SITs are Power-FETs and were invented in the 1960s. About 1980 they were manufactured and used for a short time in Japan. SITs are suitable for switching applications for high frequency, high voltage and high power. They were also used for audio purposes in amplifiers (e.g. Sony and Yamaha).

One manufacturer was the company TOKIN that seems later to have been taken over by NEC. For further information see the internet (google).

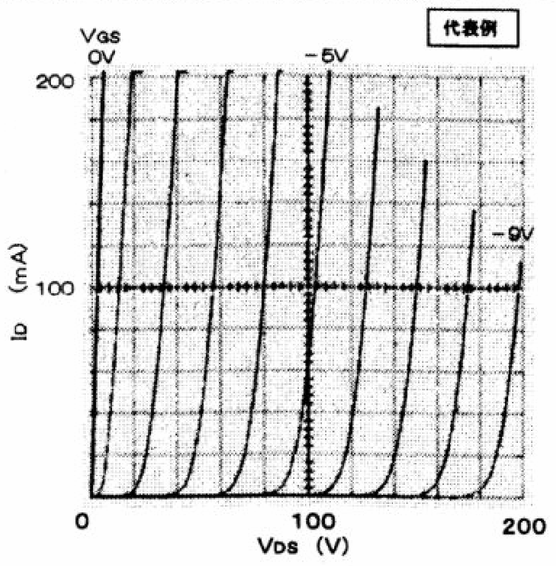
Properties of SITs:

SITs can be operated with
- a) low voltages and high currents as well as with
- b) high voltages and low currents.

Especially operating mode b) is interesting. In this mode the gate is driven with a negative voltage. The characteristic curve of a SIT then looks like that of a triode tube. In the following is an excerpt from a data sheet:

TOKIN 型番:S45F323

項目	条件	0082	0226
V_{GD}	I_G=100uA	≧450V	≧450V
V_{GS}	I_G=100uA	≧25V	≧25V
V_{DSX1}	I_D=100mA,V_{GS}=-4V	79. 9V	80. 8V
V_{DSX4}	I_D=100mA,V_{GS}=-10V	216. 1V	215. 7V
μ		22. 7	22. 5
R1	I_D=100mA,V_{GS}=0V	32. 7Ω	36. 0V
C_{GS}	1MHz,V_{GS}=-10V	531pF	568pF
C_{GD}	1MHz,V_{GD}=-10V	57. 7pF	56. 9pF



So the SIT in this mode behaves like a tube:

- powerless control
- negative voltage at the gate
- high voltage

Important difference compared to a tube: SITs are more low-resistance. With those properties one could build amplifiers that should sound similar to triode tube circuits. Due to the low-resistance also amplifiers could be built without output transformer. Modern N-channel V-FETs seem to have similar characteristics.
You can find further information in the Internet. There also seem to exist many DIY-interested persons for that field.

This article is about measuring SITs with the RoeTest.

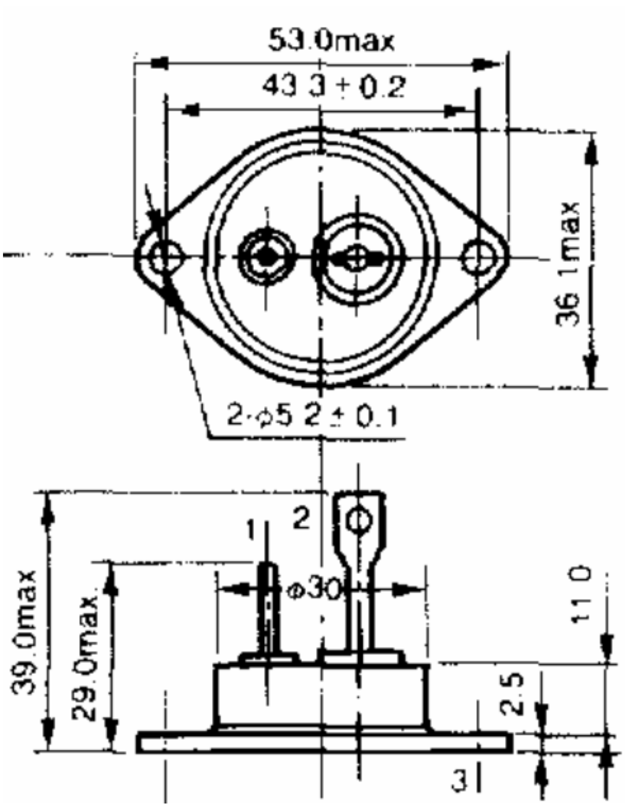
Measuring a SIT on the example of a THF-51S from TOKIN

Though the SITs have been manufactured for only a short time there still seem to be a sufficient number of NOS SITs available. There are also several offers available on Ebay.

A friendly RoeTest interested person supplied me with some samples.

First the data of the THF51

	Temperature range	G-S-Voltage	G-D-Voltage	Drain current	Total power dissipation	Max frequency	ON resistance	Turn On Time	Turn Off time
THF51	-50 … +150°C	50 V	600V	30A	400W	50 MHz	0,7Ohm max.	50ns max.	50ns max.

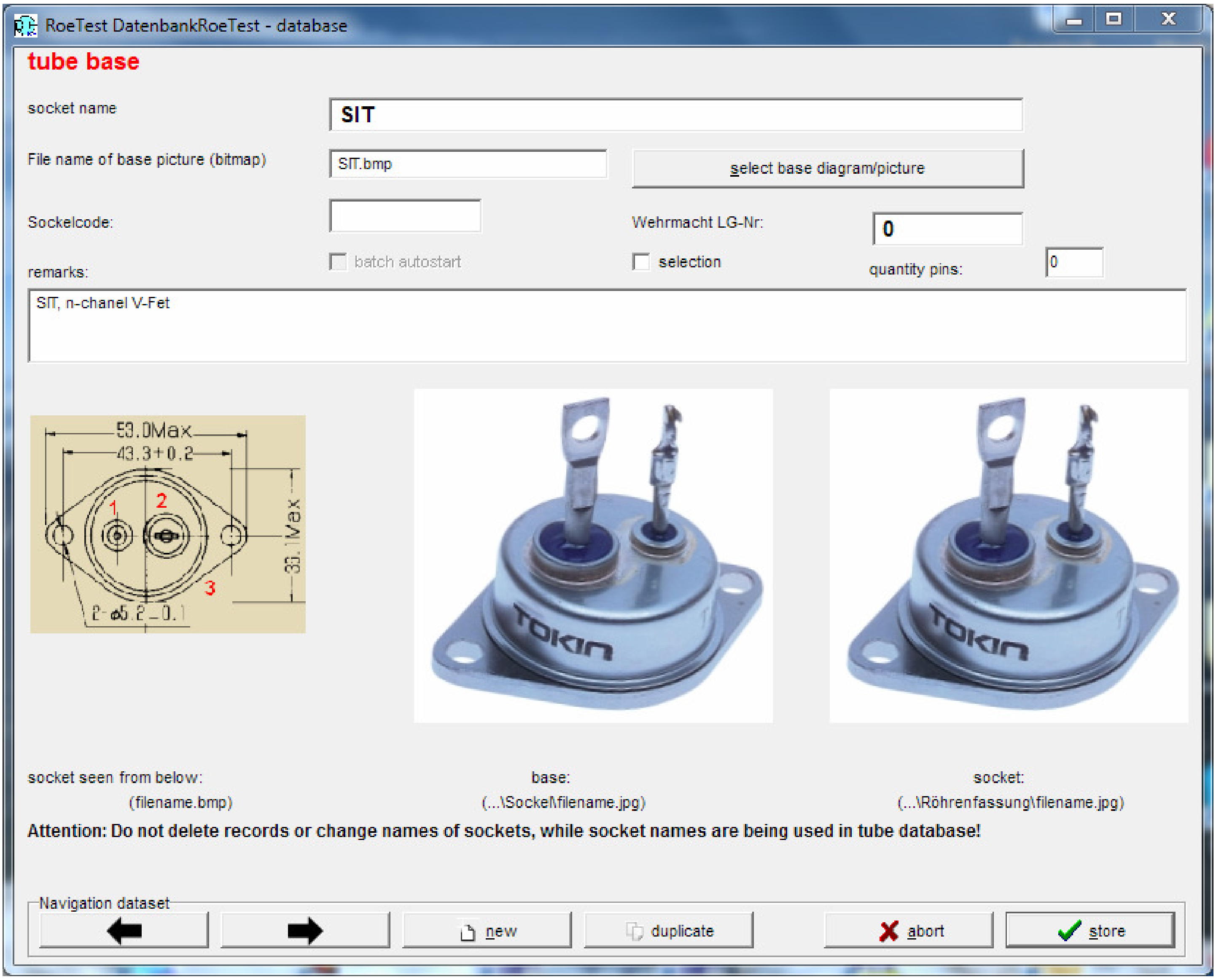


Case and pin assignment:

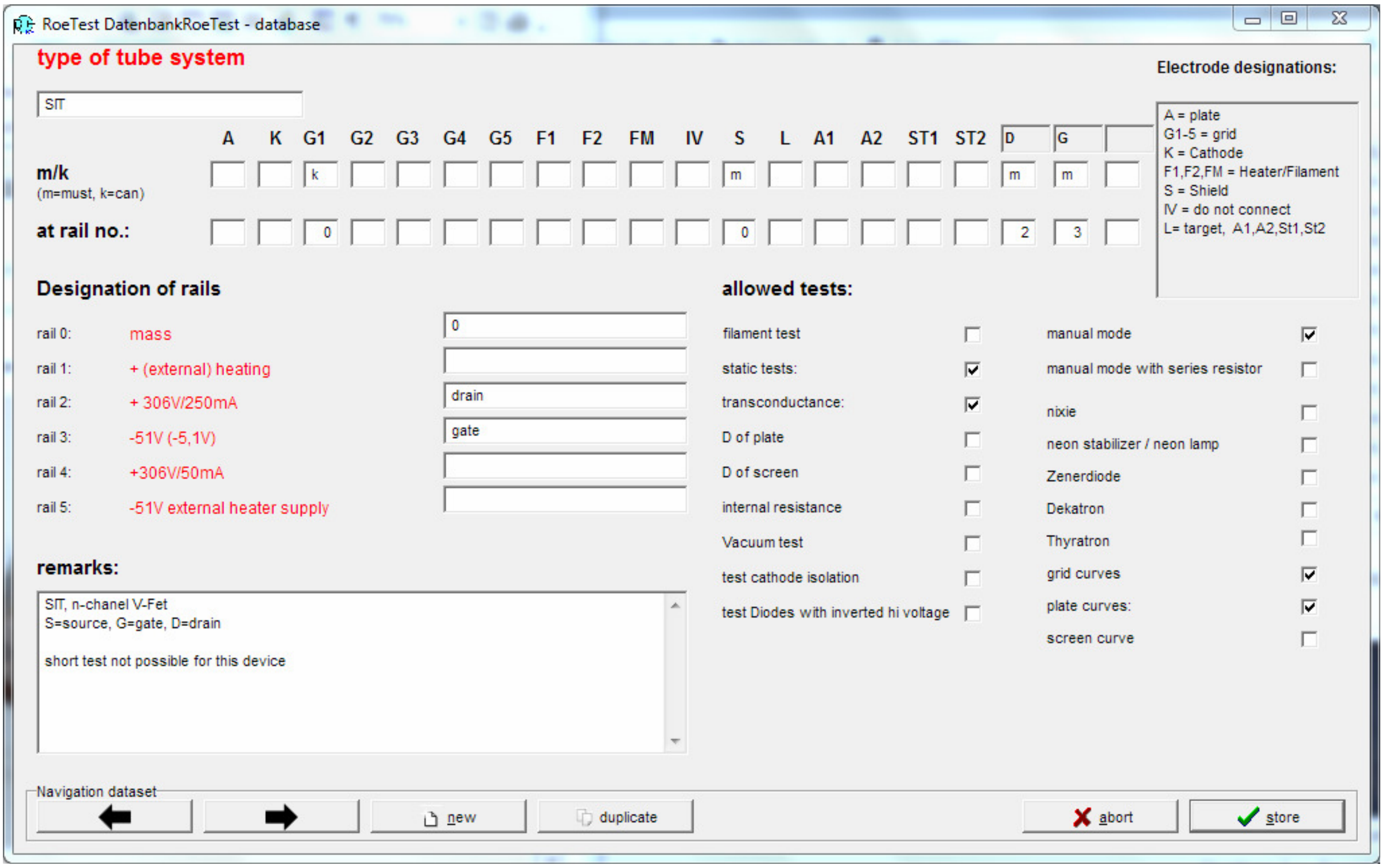
1 = G
2 = S
3 = D

In the RoeTest's databases the SIT is defined as follows:

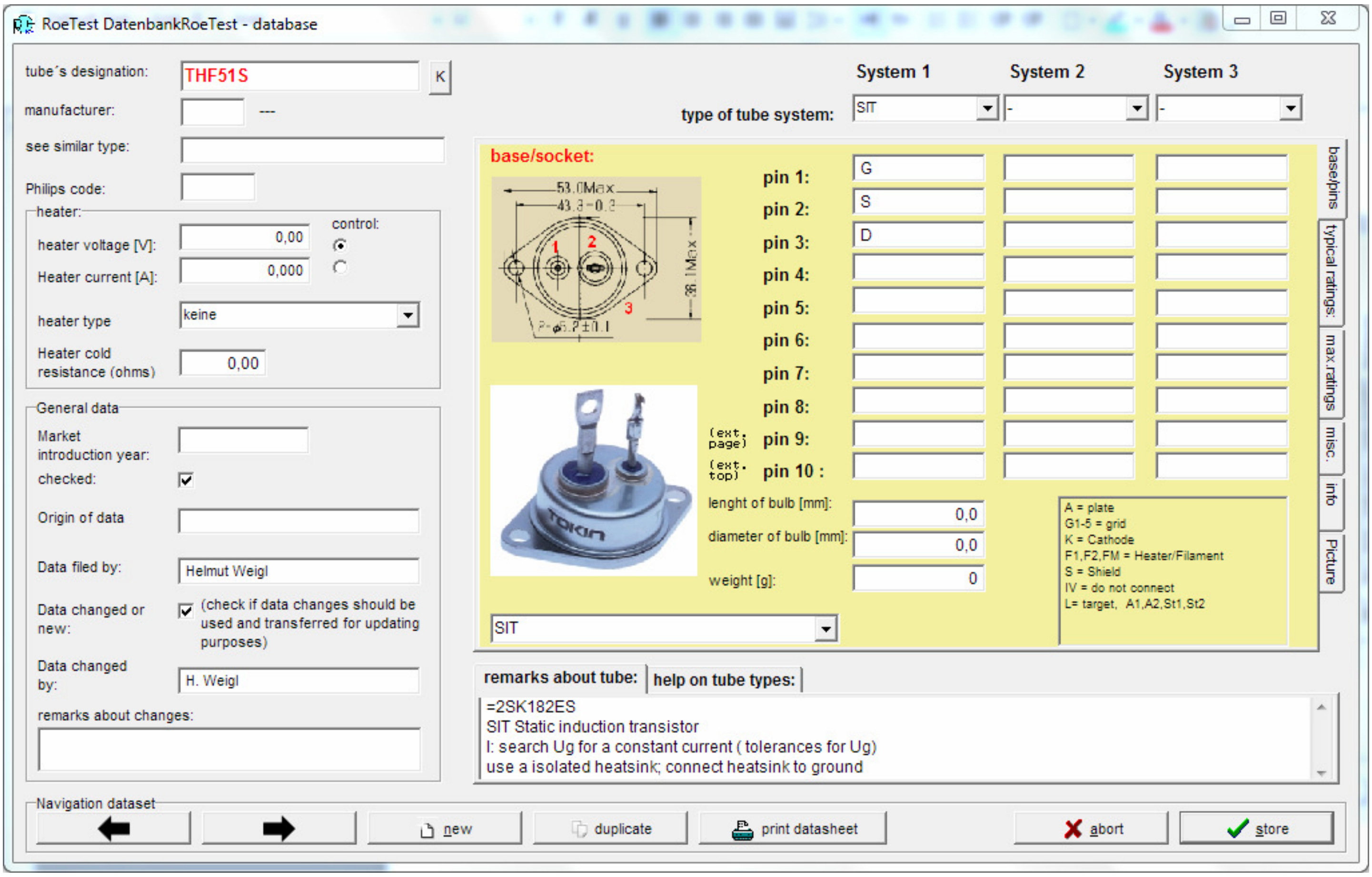
1. Socket database:

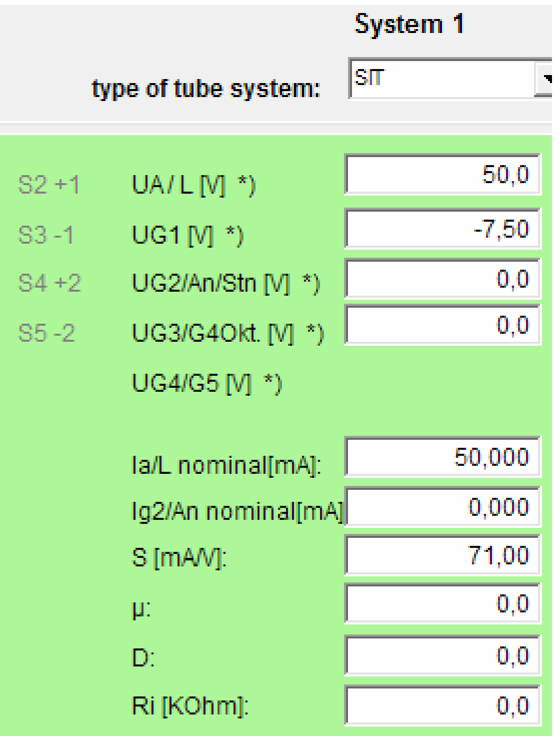


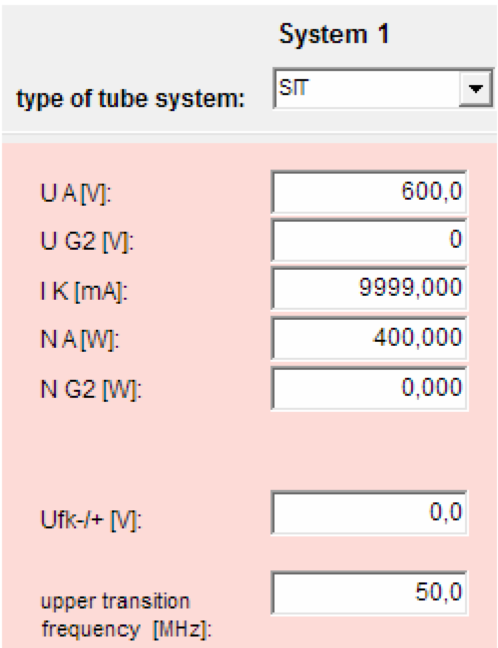
2. Tube type:


RoeTest DatenbankRoeTest - database
type of tube system
SIT
Electrode designations:
A K G1 G2 G3 G4 G5 F1 F2 FM IV S L A1 A2 ST1 ST2 D G
m/k
(m=must, k=can)
k m m m
at rail no.:
0 0 2 3
A = plate
G1-5 = grid
K = Cathode
F1,F2,FM = Heater/Filament
S = Shield
IV = do not connect
L= target, A1,A2,St1,St2
Designation of rails
rail 0: mass 0
rail 1: + (external) heating
rail 2: + 306V/250mA drain
rail 3: -51V (-5,1V) gate
rail 4: +306V/50mA
rail 5: -51V external heater supply
allowed tests:
filament test
static tests:
transconductance:
D of plate
D of screen
internal resistance
Vacuum test
test cathode isolation
test Diodes with inverted hi voltage
manual mode
manual mode with series resistor
nixie
neon stabilizer / neon lamp
Zenerdiode
Dekatron
Thyratron
grid curves
plate curves:
screen curve
remarks:
SIT, n-chanel V-Fet
S=source, G=gate, D=drain
short test not possible for this device
Navigation dataset
new
duplicate
abort
store

3. Tube data:


RoeTest DatenbankRoeTest - database
tube´s designation:
THF51S
manufacturer:
see similar type:
Philips code:
heater:
heater voltage [V]:
0,00
Heater current [A]:
0,000
control:
heater type
keine
Heater cold resistance (ohms)
0,00
General data
Market introduction year:
checked:
Origin of data
Data filed by:
Helmut Weigl
Data changed or new:
(check if data changes should be used and transferred for updating purposes)
Data changed by:
H. Weigl
remarks about changes:
System 1
System 2
System 3
type of tube system:
SIT
base/socket:
pin 1:
G
pin 2:
S
pin 3:
D
pin 4:
pin 5:
pin 6:
pin 7:
pin 8:
pin 9:
pin 10 :
lenght of bulb [mm]:
0,0
diameter of bulb [mm]:
0,0
weight [g]:
0
A = plate
G1-5 = grid
K = Cathode
F1,F2,FM = Heater/Filament
S = Shield
IV = do not connect
L= target, A1,A2,St1,St2
SIT
remarks about tube:
help on tube types:
=2SK182ES
SIT Static induction transistor
I: search Ug for a constant current (tolerances for Ug)
use a isolated heatsink; connect heatsink to ground
Navigation dataset
new
duplicate
print datasheet
abort
store
base/pins
typical ratings:
max.ratings
misc.
info
Picture


System 1
type of tube system:
SIT
S2 +1
UA / L [V] *)
50,0
S3 -1
UG1 [V] *)
-7,50
S4 +2
UG2/An/Stn [V] *)
0,0
S5 -2
UG3/G4Okt. [V] *)
0,0
UG4/G5 [V] *)
Ia/L nominal[mA]:
50,000
Ig2/An nominal[mA]
0,000
S [mA/V]:
71,00
µ:
0,0
D:
0,0
Ri [KOhm]:
0,0


System 1
type of tube system:
SIT
U A [V]:
600,0
U G2 [V]:
0
I K [mA]:
9999,000
N A [W]:
400,000
N G2 [W]:
0,000
Ufk-/+ [V]:
0,0
upper transition frequency [MHz]:
50,0

First there arises the question if a SIT can be measured with the RoeTest?

Yes it can be measured but there are in fact some differences compared to a tube.

Tubes: There exists a cathode that wears out with the time in use. The main purpose of a classic tube tester is to determine how far a tube is worn out. This means if the tube is good, still usable or unusable, or how many % the plate current differs from the manufacturer's data.

SIT: This semiconductor component has no wear out like a tube. So it makes no sense to test it the same way as a tube and to calculate a %-value or make a good/less good/bad statement.
There exists only one criterion: works/does not work. But a SIT has larger parameter variance.
The question here is: What gate voltage is required for a given drain current? (this can be measured with the RoeTest).

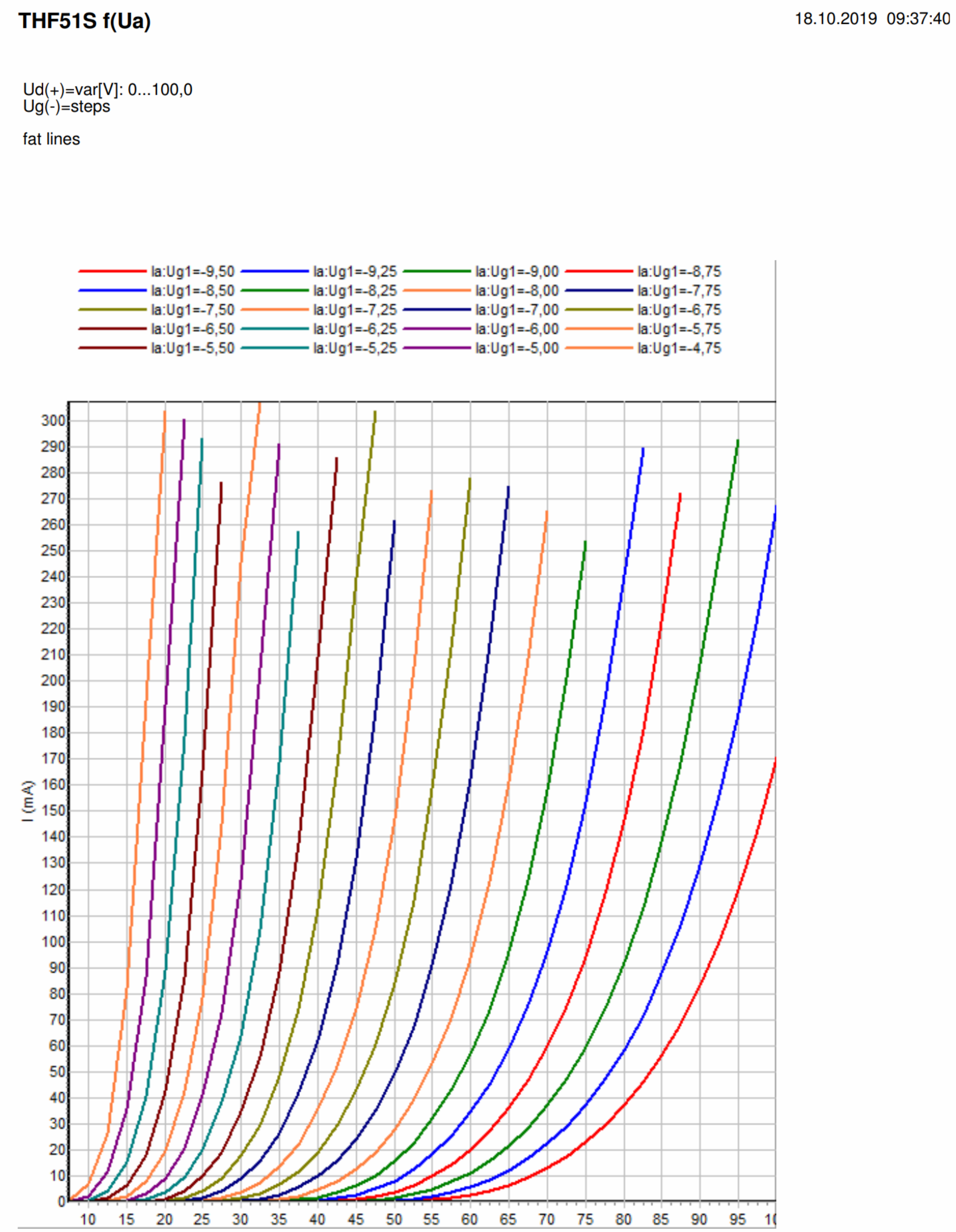
The SIT has no filament, so heating up and waiting is not required. Of course there is also no filament test possible. Checking for shorts, as for the electrodes of tubes, is not possible with the RoeTest (and not required).

As there exist large parameter variances, it may be that the auto-start current for the RoeTest is too small. Then measurement can be started manually or a fixed startup time of 5 seconds can be selected.

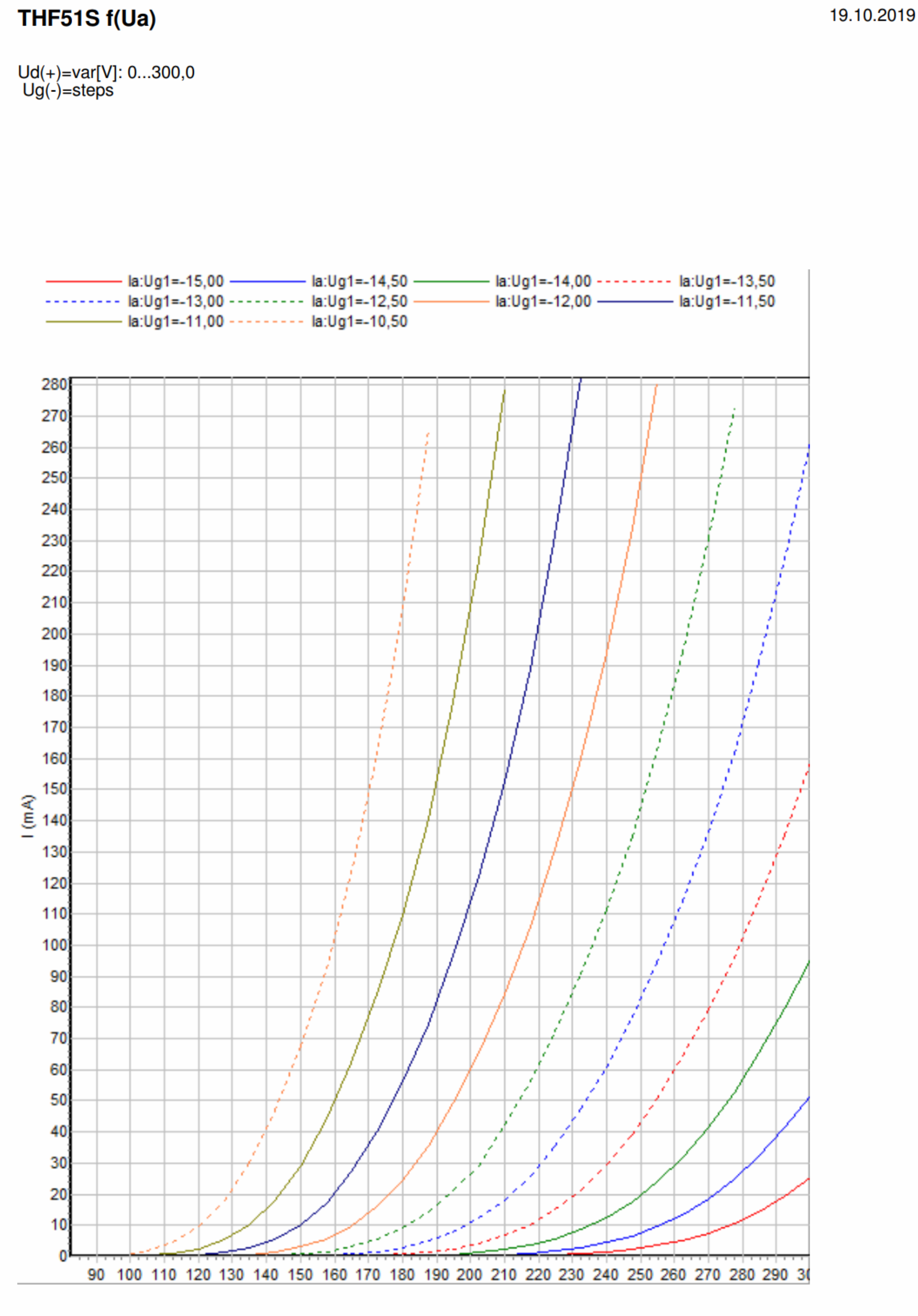
SITs have a very high conductance. I measured for the THF51S a conductance of more than 230 mA/V (in the upper region of the characteristic curve). This may lead to measuring problems as the SIT tends to oscillate. On the other hand I have found that there were no problems up to a drain voltage of 340V and a drain current of up to 300 mA. With drain voltages above (tested up to 450V) the SIT will self oscillate and no measurement is possible. I tried to damp the oscillation with chokes, resistors and capacitors but were not successful. So I decided not to make tests at those high voltages to not endanger the RoeTest and the SITs.

First characteristic curve recording:

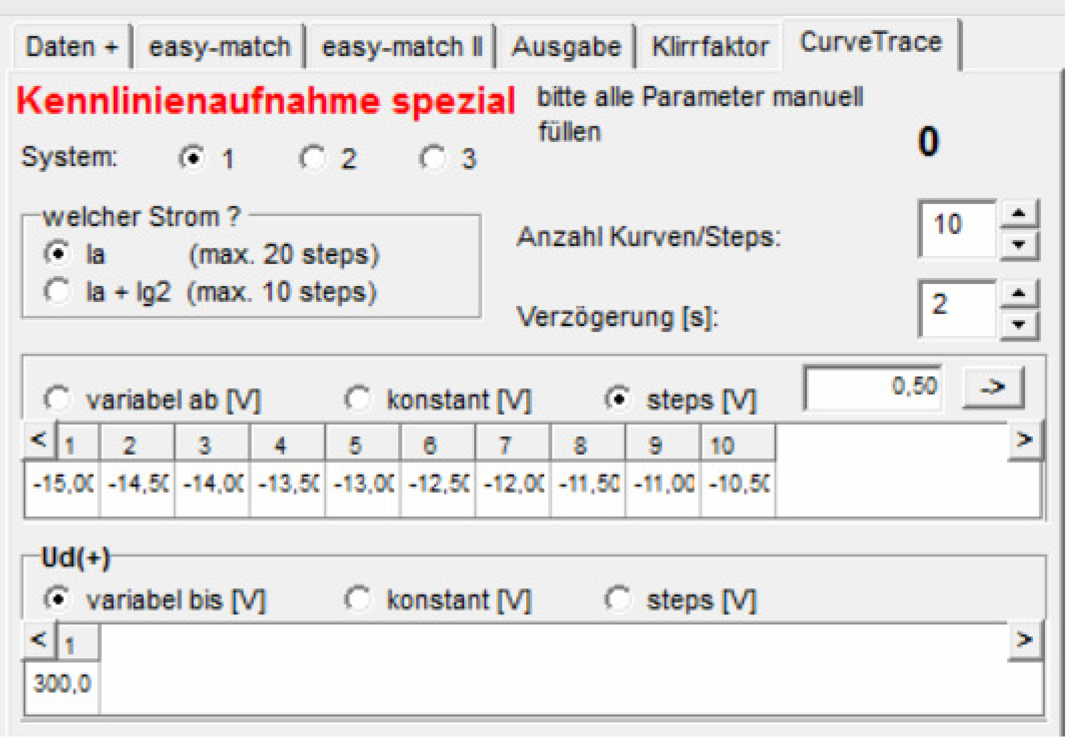
first for Ud up to 100V:



then for Ud up to 300V:



Settings of the RoeTest Curve-Trace for the characteristic curves above:

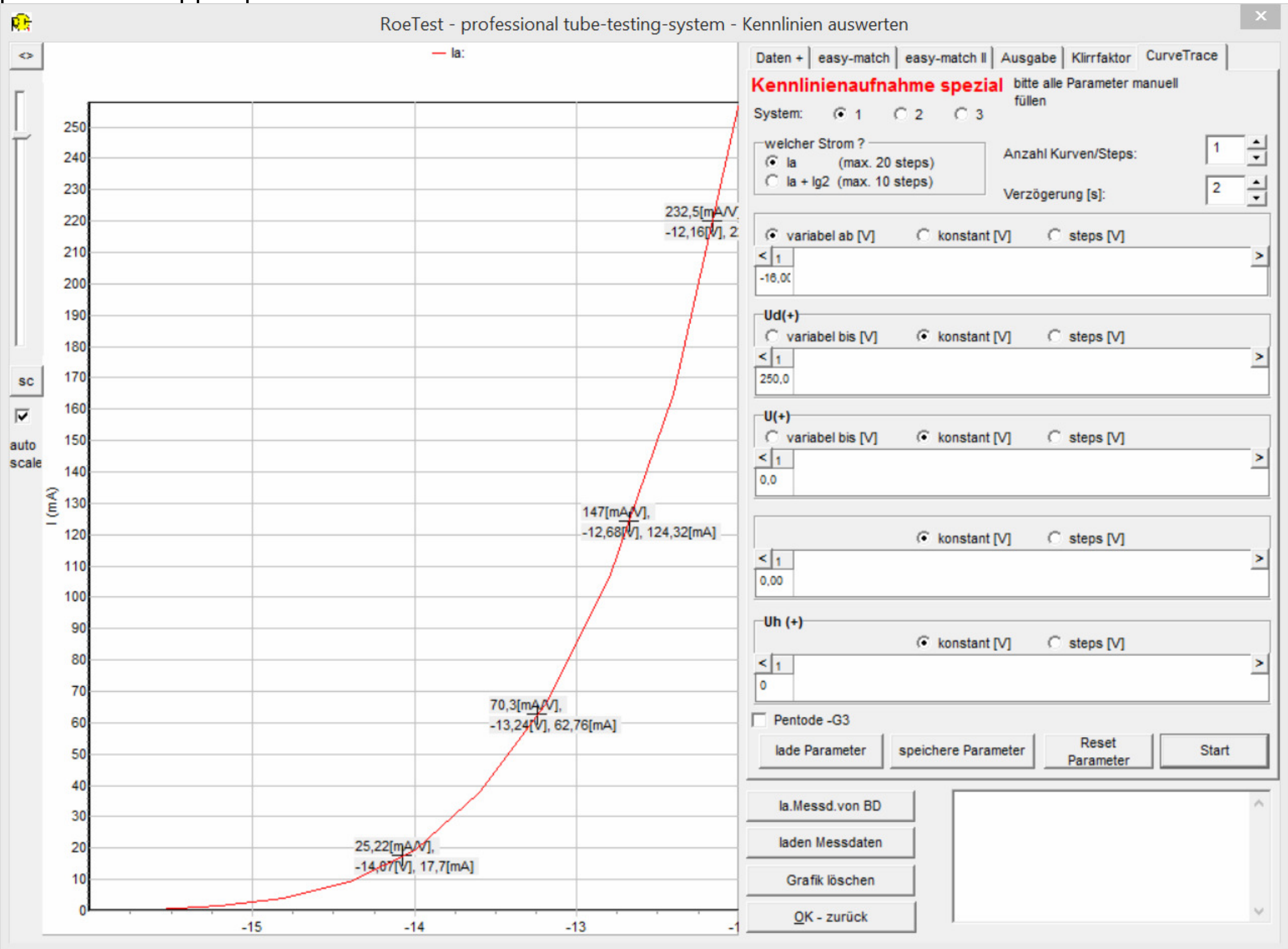


the characteristic curve f(Ud) is recorded

The characteristic curves correspond to the data sheets of the SITs.
So measuring characteristic curves with the RoeTest is possible.

Of course it is also possible to record characteristic curves for f(Ug).

I entered some measuring points on the curve that show the large conductance of the SITs in the upper part of the characteristic curve. Due to the fact that there were only a few measuring points in the upper part of the curve the curve has some small bends:



RoeTest - das Computer-Röhren-Messgerät -

professional tube-testing-system (c) Helmut Weigl www.roehrentest.de

Measuring what Gate-Voltage is required for a given Current:

Ud and Id must be set in the tube data as follows:

typische Werte:	
UA [V]	50,0
UG1 [V]	-7,00
UG2 [V]	0,0
UG3 [V]	0,0
IA [mA]	50,000

The function search for Ug ('Ug suchen') can be found in the RoeTest software under batch processing:

☑ Schnelltest ☑ Ug1 suchen für IaKonst ☑ Steilheit bei neuem Ug1 rechnen

Result:

COM 20 Data In Data Out Kühlkörpertemp

Meldungen | Heizung | Kurzschlusstest | statische Daten | Vakuum | Kennlinien | Bemerkung

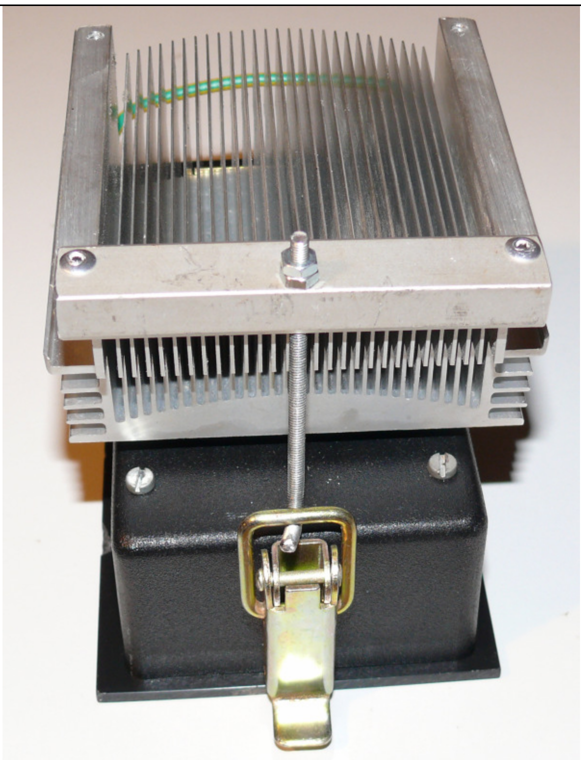
System	1	2	3
Röhrenart	SIT		
Sollwert IA [mA]	~~50~~		
Messwert IA [mA]	~~28,94~~	49,94	
= % vom Sollwert	~~58~~	Ia/Ug1=	
Sollwert IG2 [mA]			
Messwert IG2 [mA]		-6,75	
= % vom Sollwert			
S [mA/V]		109,09	
bei Delta UG1 [V]		0,6	
Messwert IA[mA] bei +1/2 dUG1		91,19	
Messwert IA[mA] bei -1/2 dUG1		25,737	
µ			
D Anode [%]			
Messwert IA [mA]			
bei UA [V]			
D G2 [%]			
Messwert IA [mA]			

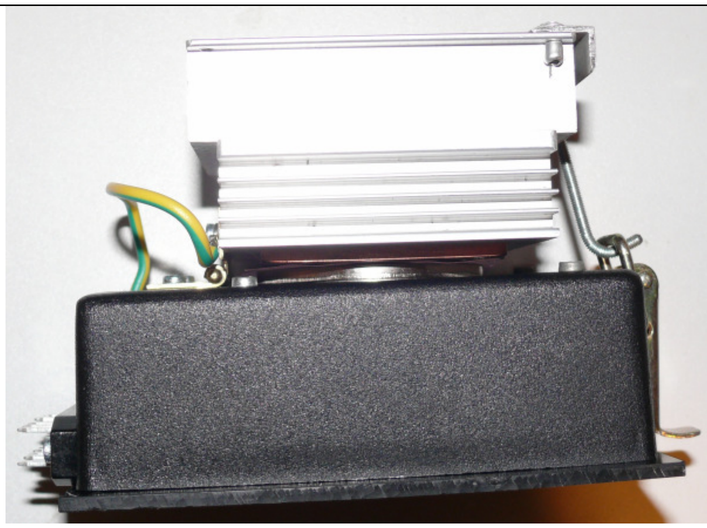
With Ud of 50V and Id of 50 mA we need a voltage **Ug** of **-6,75V** for this example.

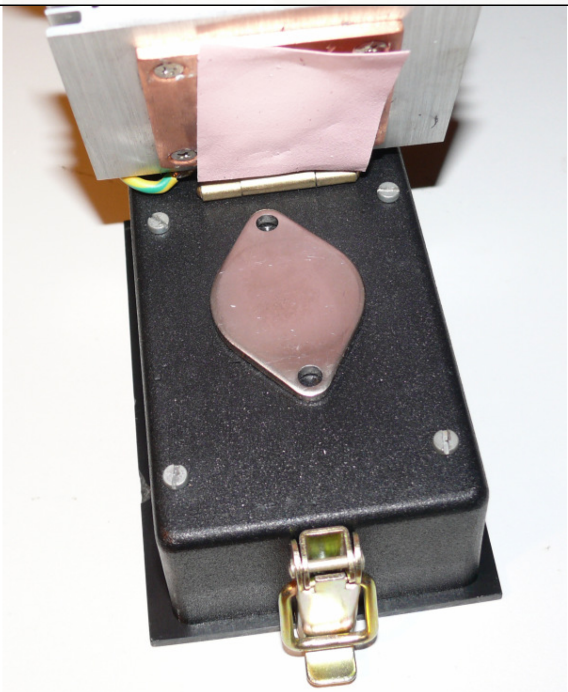
(Note: the RoeTest software has been developed for tubes and so the values are shown as Ia and Ug1 instead of Id and Ug)

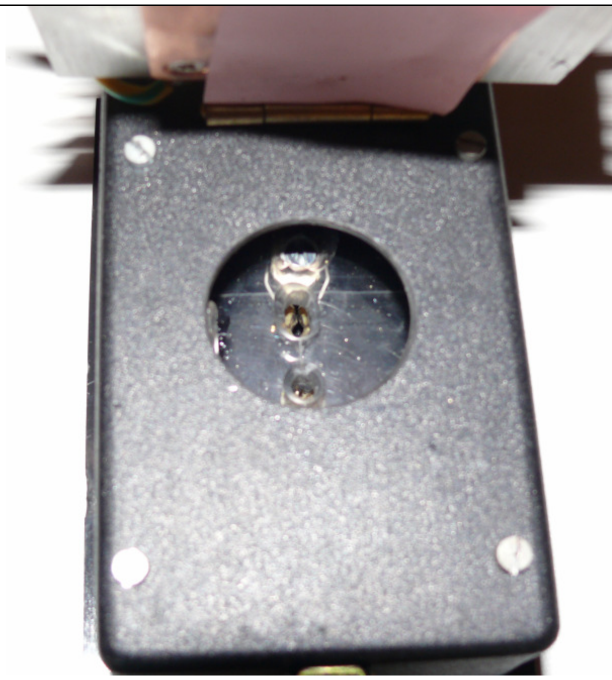
Socket box:

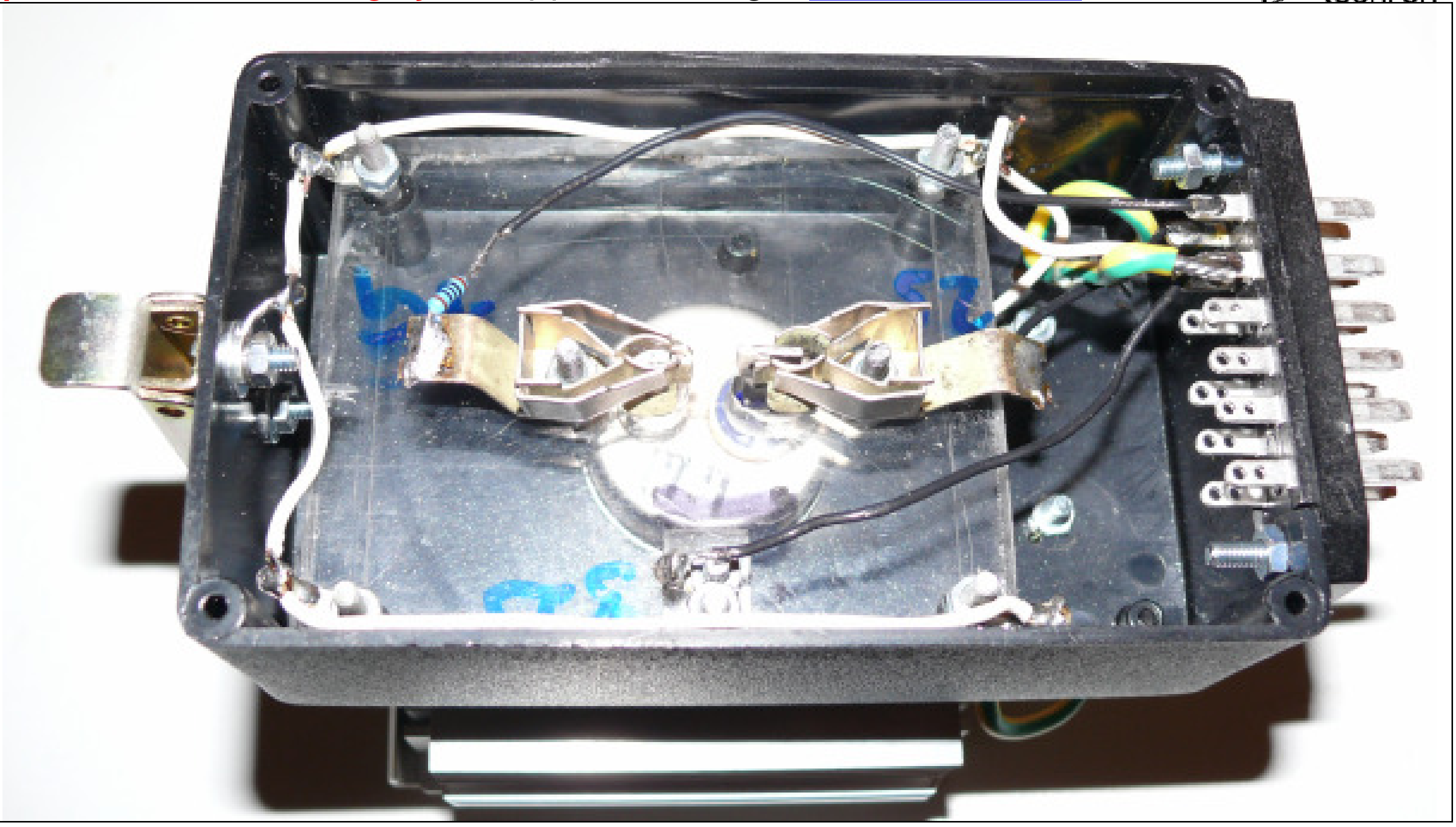
You can connect the SITs with alligator clips to the RoeTest. But better (safer and quicker to change) is the use of a socket box. There exists no socket for the THF51 so I found my own solution (see the pictures). Important: A small heat sink for the SIT. Normally the SIT will not warm up due to the short measuring periods. But operating the SIT at longer intervals at high power could lead to overheating of the SIT. Isolate the SIT from heatsink with a thermal contacting foil. A closed socket box also serves as touch protection.











Comparing SITs for same given Id (search for suitable Ug):

There were 4 parts available with different markings:

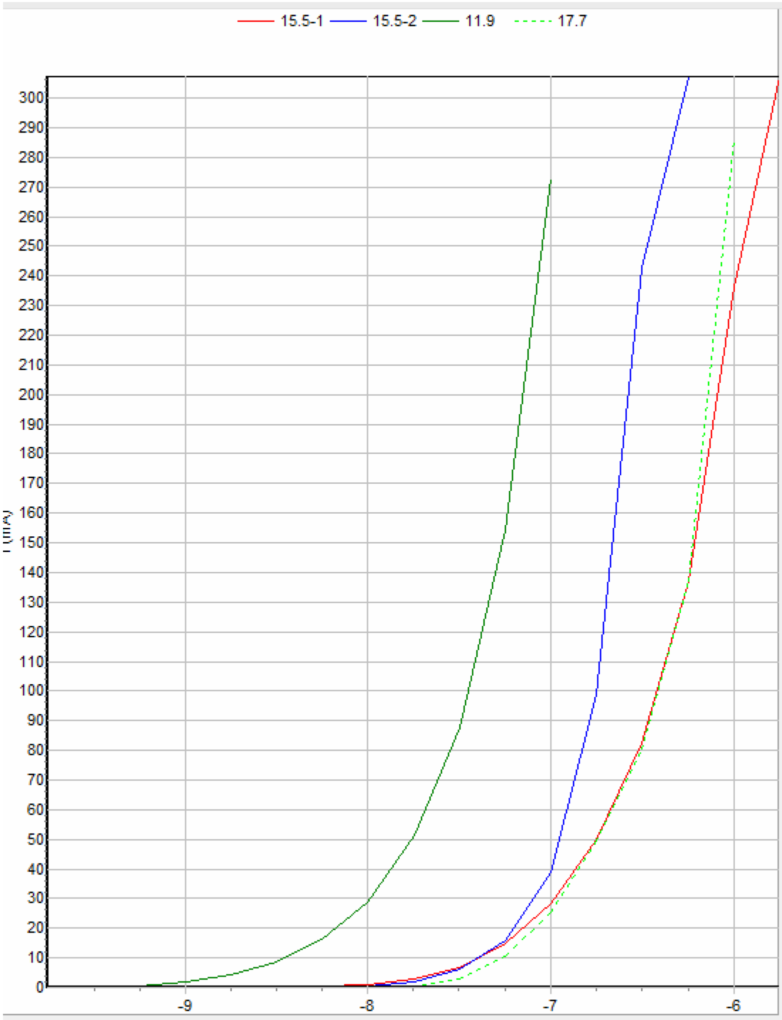
Marking THF51S:	15.5-1	15.5-2	11.9	17.7
	found Ug [V] for Id=50mA			
Ud=50V	-6,775	-6,95	-7,775	-6,75
Ud=100V	-9,025	-9,25	-10,25	-9,075
Ud=300V	-14,575	-15,075	-16,125	-14,55
	found Ug[V] for Id=100mA			
Ud=50V	-6,425	-6,75	-7,45	-6,4
Ud=100V	-8,6	-9,025	-9,825	-8,65
Ud=300V	-13,975	-14,7	-15,55	-14,05

Result: The voltage Ug required for a given Id differs a lot for the available 4 parts. So when using SITs in an amplifier circuit Ug must be adjusted very carefully. Also care must be taken when adjusting Ug as due to the large conductance a small change of Ug will lead to a large change of Id.

The parts marked 1.5-1 and 17.1 do match best.

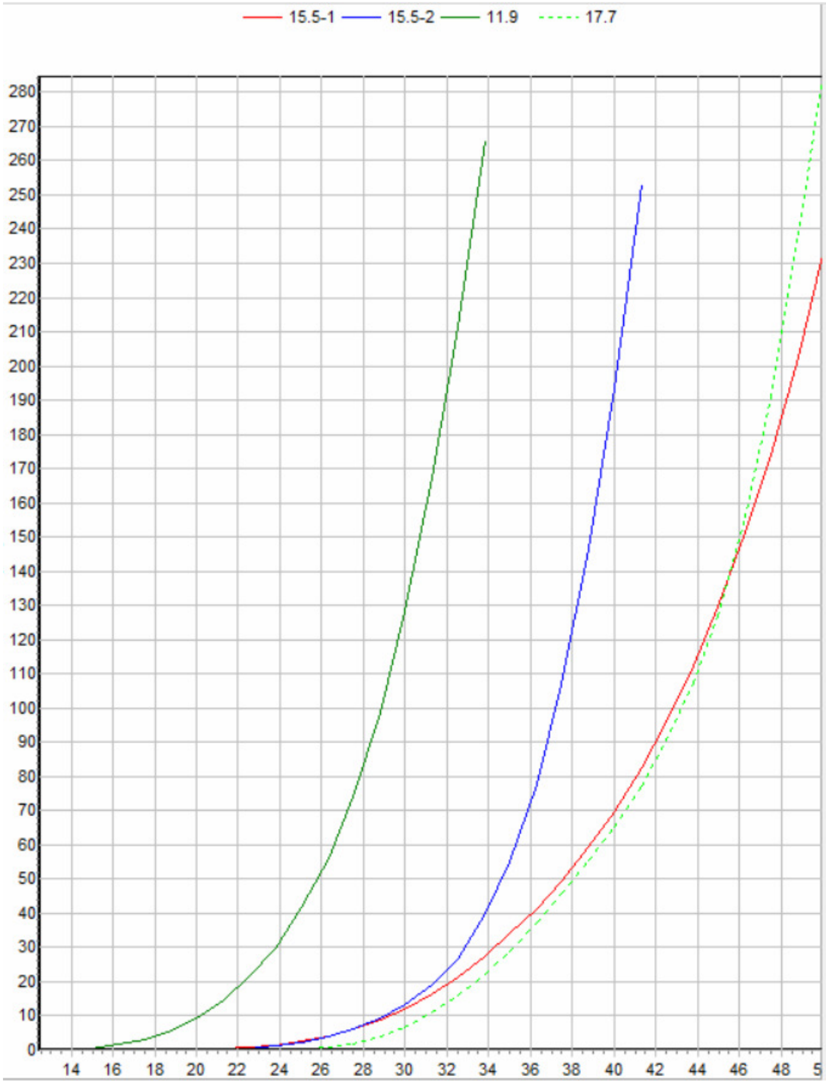
Comparison of SITs from their characteristic curve

1. Comparison by f(Ug)
at Ud=50V:



Parts marked 15.5-1 and 17.7 match good.

2. Comparison by f(Ud)
at Ug=-6V:

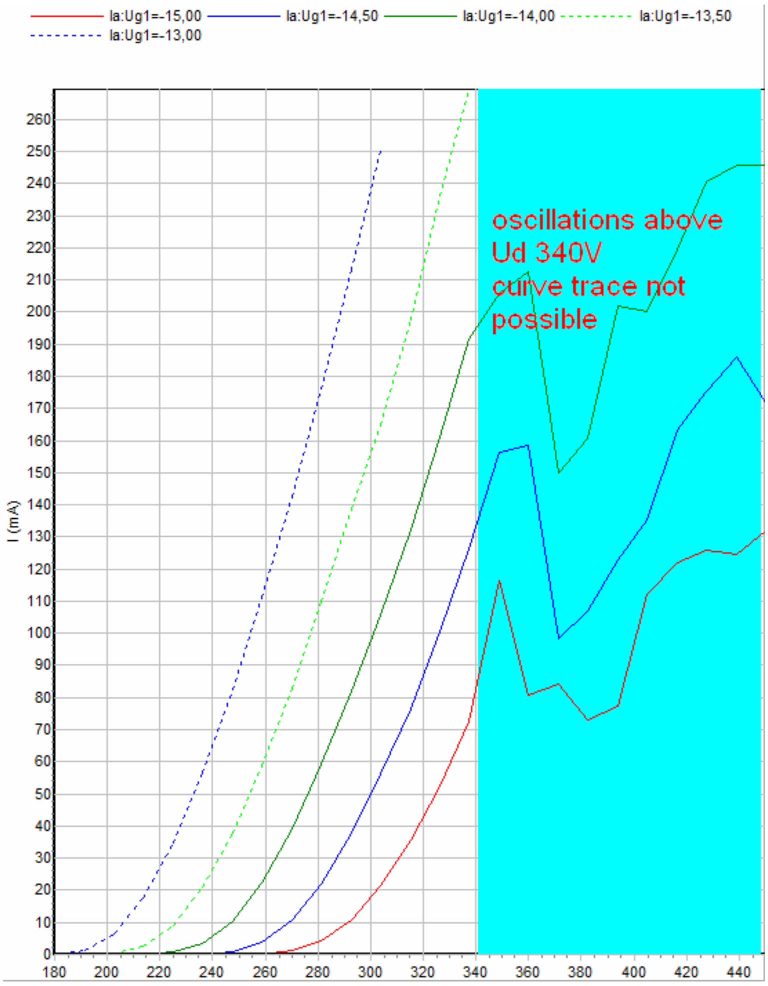


Again the parts marked 15.5-1 and 17.7 match good.

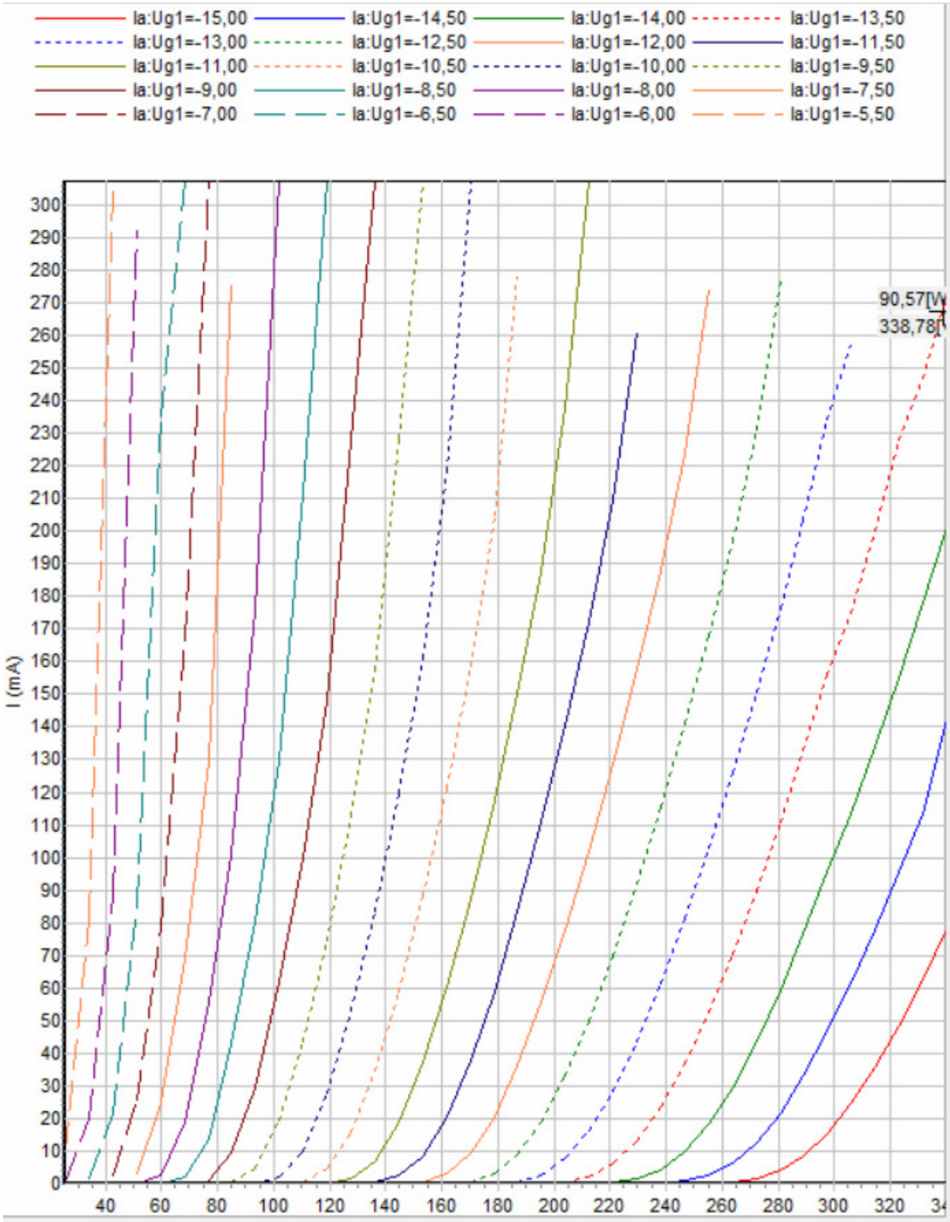
Matching of SITs is best done by comparing their characteristic curves. For comparing the f(Ud) curves should be preferred due to their better resolution. Like with tubes, comparing SITs only at a given operating point is not sufficient (see the table above – search for Ug).

What cannot be done:

Above Ud of ca. 340V the THF51S tend to strongly oscillate. Therefore measuring curves above this voltage is not possible with the RoeTest.



maximal possible curves (up to 340 V Uds):



Notes regarding the maximum supply voltage in circuits:

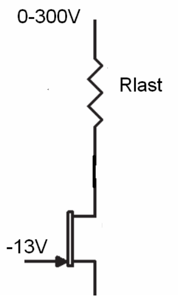
The THF51S can sustain up to 600V. When operating it with an inductive load (e.g. a transformer) the self-induction has to be taken into account. To avoid overvoltage and destruction of the SITs I recommend not to exceed 300V supply voltage.

When using pure resistive loads higher supply voltages can be used. In this case part of the voltage is dropped across the load resistor. So the voltage across the SIT is reduced dependent on the load current.

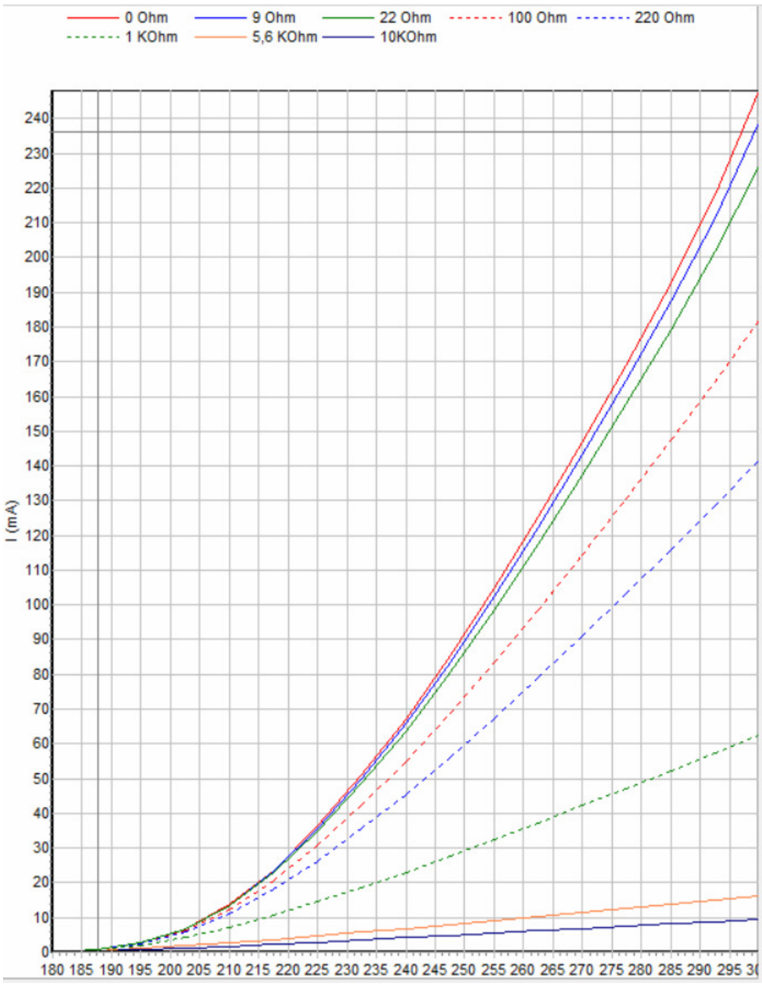
The SIT in a Circuit with Load Resistor in the Drain-line:

In a real-world circuit the curves change depending on the load resistor. So in real circuits not only the characteristic of the SIT has to be taken into account but also the interaction with other components.

The following graphics shows SIT curves at different load resistors. Different load resistors were used in series with the drain-line:



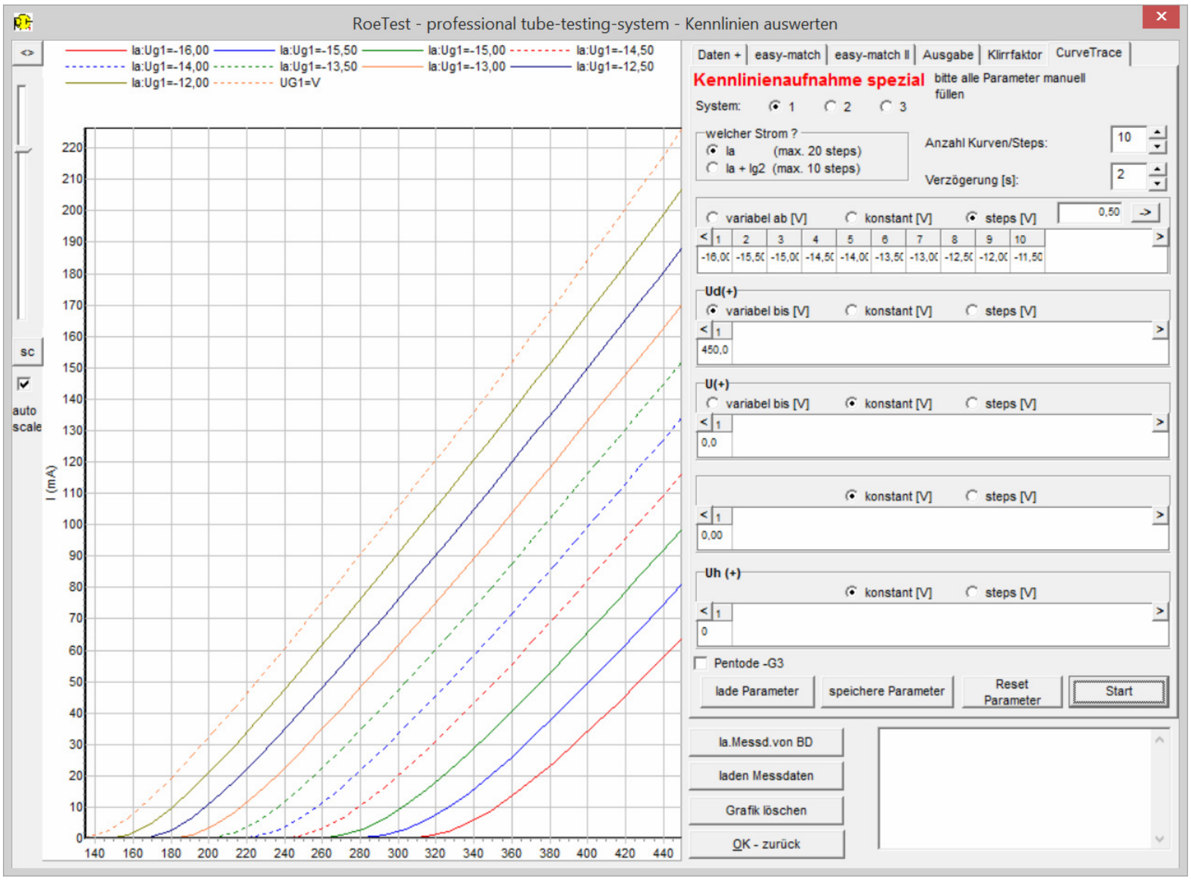
Ug1=-13V, Variation of Supply voltage up to 300V



You can see the curve's dependence from the load resistor.

With a load resistor in the drain-line higher supply voltages are possible before the SIT starts to oscillate. This is due to the fact that part of the supply voltage is dropped across the load resistor.

Here an example:
Supply voltage up to 450V, Load resistor 1 KOhm



Result: The RoeTest can also measure the semiconductor device SIT in many ways.