RoeTest Rebuild
of Frank Theis 2014
Report of 01/17/2015

<u>Characteristics:</u>

Hardware:	Version 7.2 + Voltage Upgrade V8.0
Firmware:	Version 7.2
Software:	Version 7.8.0.0
Production:	10-2014 to 01-2015
Finished:	01/17/2015
Worktime:	160h
Material:	1.200€
Design:	19“-Tabletop Unit with Front Adapters

Background:

About forty years ago I started to work with electronics using the tube technology of that time. In the seventies the semiconductor technology replaced the tubes and also my every day's electronic work was no longer related to the good old tubes. Today, almost any imaginable electronics especially concerning audio is only available in digital, perfect but characterless and generic form. Slightly I start missing the not perfect but spirited sound of the good old tube technology and would therefore like to build tube amplifiers as my next hobby.

And for this I miss a system, which is able to characterize and match audio tubes precisely on a high performance level. Classic tube testers were not built for this challenge and do not fit to this requirement. So I investigated the availability of the best possible tube test system for this all over the world. And the result was – what a miracle – Helmut Weigl's RoeTest system, offered only a few miles away within our region. This system is already well known all over the world. The system, its genius concept, the possibility to rebuild it and its excellent price-performance ratio inspired me immediately and therefore I build such a system on my own.

In this report I describe my rebuild experience for others, as all the nice reports of RoeTest rebuilders inspired me a lot and also assisted me in a noticeable way.

My ideal system:

For me and my electronic lab a 19“-system with front plug-in tube adapters seemed to be the best solution. Cased systems like the original RoeTest design are useful for frequent transportations, which are not expected for my system. Therefore I decided to build my personal RoeTest based on the latest hardware version V7.2 using a 19” system carrier.

The electronic kit:

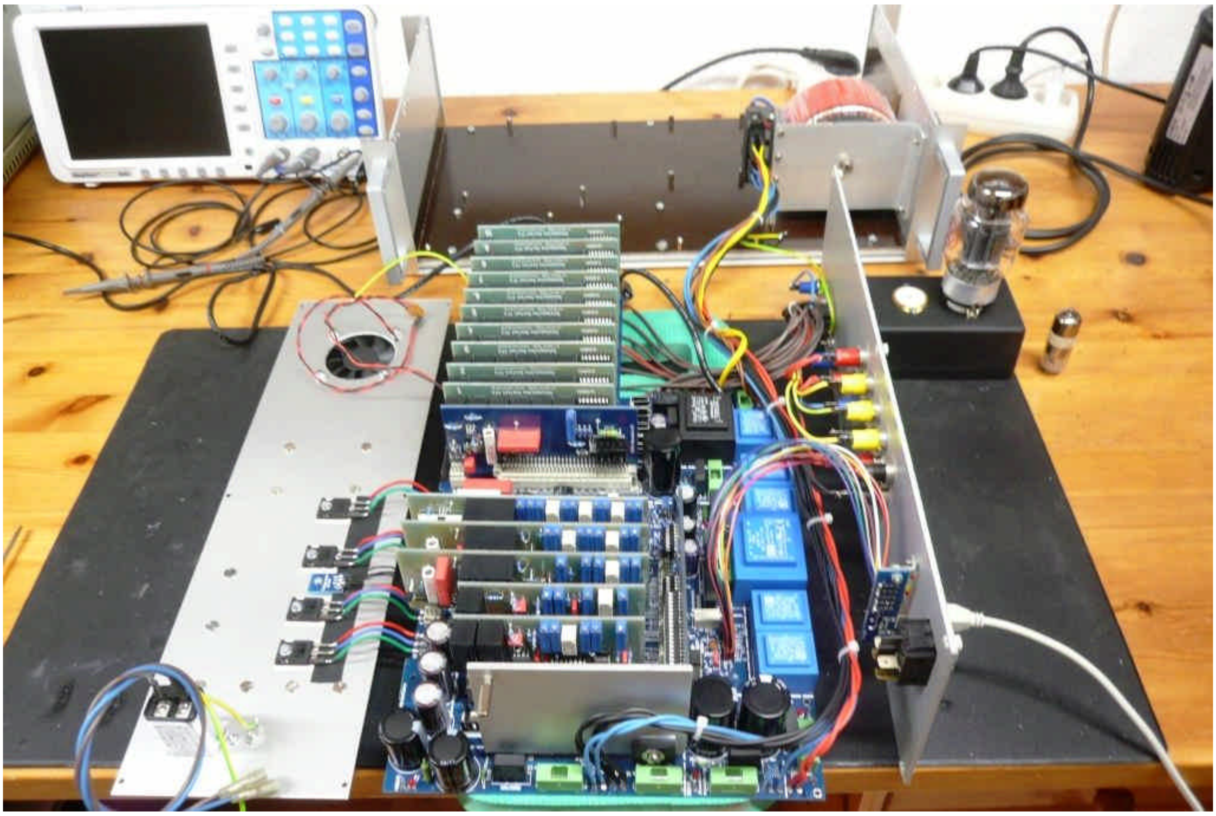
Helmut Weigl is selling a pretty nice set of pcbs, transformer, microcontroller, software and in addition some of the difficult to purchase components for a really good price. All of the other components I ordered at the German supplier Reichelt by using the components database and the Reichelt-import-function. Some of the positions went lost and I had the reorder them in a second step.

The housing for my system I ordered also at Reichelt, it is a cost effective 19“ tabletop housing (article GEH SG 1-19, gietec, 84TE width, 3HE, 24cm depth) with additional front panel and some 19” mounting material. This housing supplied as a kit is quite simple but works fine as it is already supplied with heat spreading slots in top and bottom cover.

As next step I enjoyed to assemble the pcbs in 25 hours very carefully, which is easy to do as the pcbs have all the components values printed on the board. For some components the grid is not perfectly adjusted to the components needs, but nevertheless the components still fit into the pcbs correctly. Sometimes I missed a kind of part numbering for the components to identify them in the circuit diagram. This always takes some time here to look at the traces backwards to identify them.

Afterwards I have – as I'm impatient – started the first test run without main transformer and without voltage regulators, just using microcontroller card and relay cards. And look! The system worked fine from the very first beginning, communication with the PC without any problems, the relays acted as expected. I had not expected this without any failure analysis, but careful assembly on perfect pcbs pays off.

From now on the whole mechanical part was constructed and built and then step by step additional parts of the electronics were taken in order. Here also the system worked always immediately perfectly stable, no failures occurred. Here is a picture of the proceeding system after some further steps of integration:



Only the upgrade for extended voltage ranges of "version 8" went lost during the first assembly and I had to replace the affected components later. This also worked pretty fine without any problems.

The electronic kit in the latest version has reached an extremely high grade of maturity and an excellent level of rebuild ability. I would give the electronic kit a clear rating for „professional class", absolutely perfect. During the last 30 years several electronic kits carried me away, but I never had such a positive experience like with RoeTest. It must have taken Helmut Weigl endless working hours and optimization steps, to finally achieve this extreme high level of maturity.

Congratulations for this perfect result, especially for those who build this system on their own. It is great fun to rebuild such a system without having any kind of trouble.

The 19“ mechanics and its special issues:

Adjustment of the main pcb:

Generally the 19“ implementation works fine as the main pcb with its width fits into an 19“ carrier with 84TE leaving about 2mms space on both sides. The interesting point is the depth of the carrier. In original state the main pcb has a depth of 254mms and not as described in the manual only 230mms. My cost effective 19” carrier built by gietec has an overall depth of 240mms and the inner depth of the housing only leaves less than 235mms for the electronics.

Therefore I had to reduce the depth of the main pcb by 19mms. This can easily be done by a tile cutter very precisely. These 19mms contain the usb-interface and the additional front plugs, which are not required in my application. The cutout usb-interface is assembled to the front panel in my system (this is already prepared in the “version 7.2” main pcb with a small connector close to the microcontroller card) and the additional tube signals can also be picked up at the bottom side of the main pcb (see picture above of the already prepared main pcb and other pictures below for bottom side of main pcb).

It does make sense to avoid signal stubs on the pcb leading to the original usb-interface position (usb signals are pretty fast). Here you can easily cut these stubs on the top side of the pcb with a small drill as those signals only lead to the original usb position (only for “version 7.2, version 8 no longer contains this additional connector).

So 19mms depth’s reduction is not a big deal (takes 5 hours of work for careful proceeding).

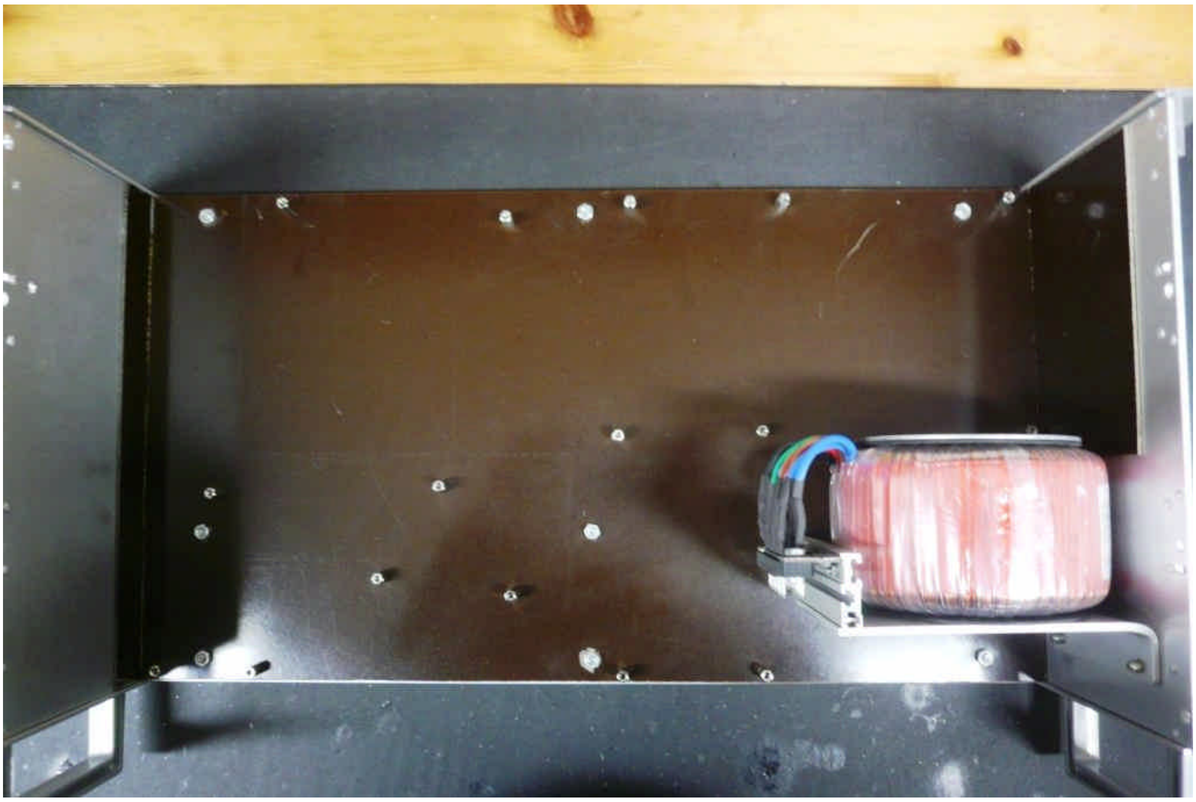
Base plate and transformer in vertical position:

As mounting carrier for the main pcb I cut a 3mm aluminum plate to the required size, integrated it into the 19“ carrier and finally isolated it laminar and in the critical areas using isolation material (Pertinax). Especially at the side areas and at the position of the last relay card careful isolation of the 19” carrier is urgently required to achieve an acceptable security level here.

The 10mm bolts for the main pcb screws (3mm threads on both sides of the hexagonal bolts) can directly be screwed onto the base plate (from bottom side). This leaves enough space below the main pcb for wiring.

In addition the space inside the small 19“ carrier is so narrow, that the main transformer has to be mounted in vertical position. For this I bended a heavy aluminum carrier, which is screwed to the side plates of the carrier.

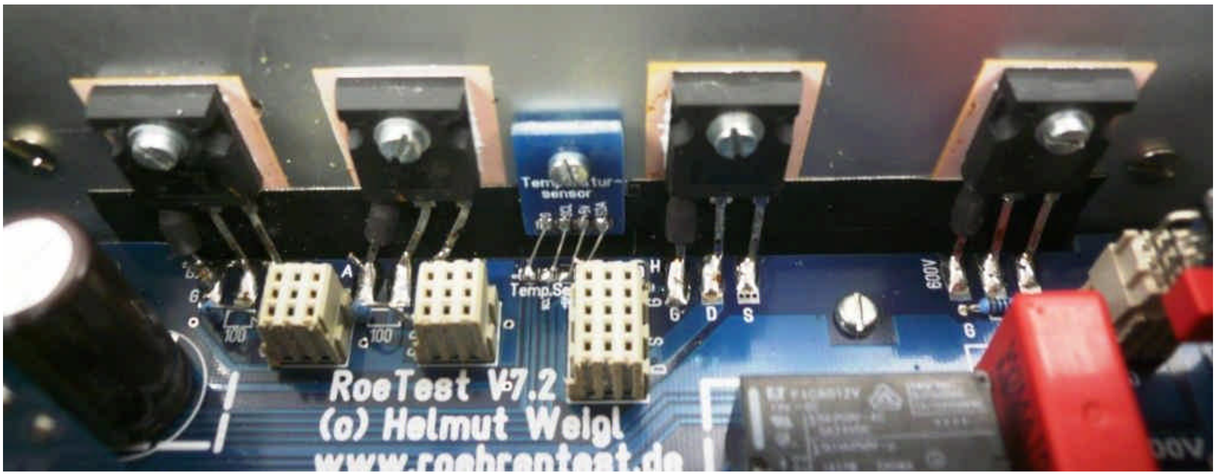
After these basic work steps (about 25 hours of work without professional mechanic machines) the prepared mechanical platform looks like this:



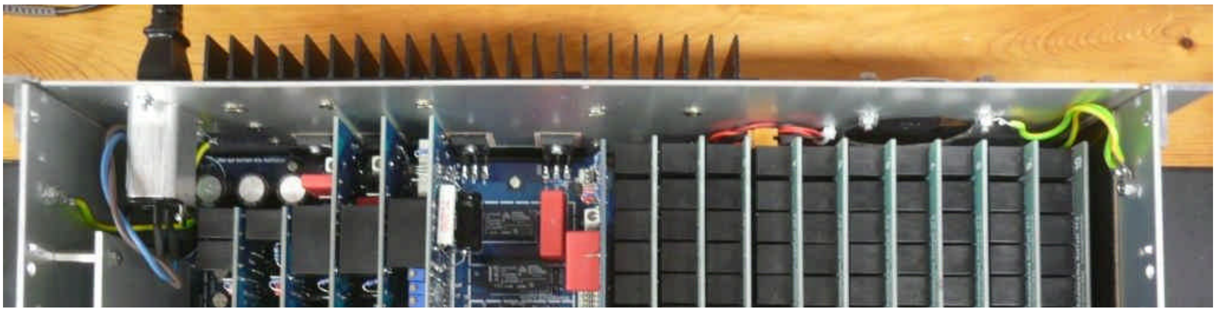
Cooling heater rectifier / Back panel cooling regulators:

As the isolated base plate cannot work as cooler for the heater rectifier (low voltage heater) I used an aluminum plate on the component side of the main pcb, which is connected to the system carrier by a bolt.

Basically the cooling of the regulator transistors has to be performed at the back panel. In my first shot the transistors in vertical position are screwed to the back panel exactly positioned between the regulator cards including the thermal sensor. Here is one of the bottle necks inside the compact low cost housing. There is almost no space left, very tricky:



An aluminum cooler with about 1K/W it mounted onto the outer side of the back panel to dissipate the heat of the regulator transistors:



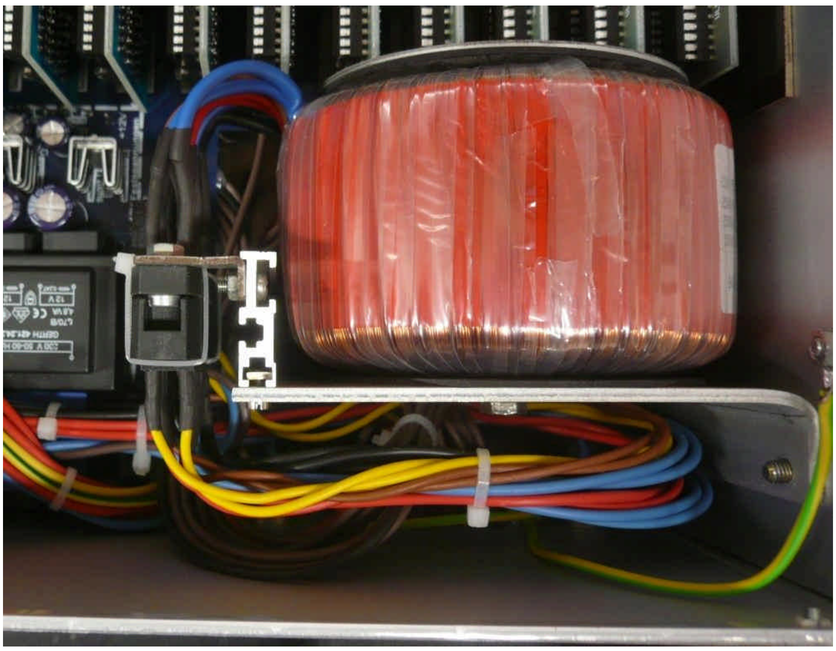
Beside the cooler there is a small fan transporting heat out of the housing, as soon as the thermal sensor has reached the adjusted temperature limit.

Cabling inside the housing:

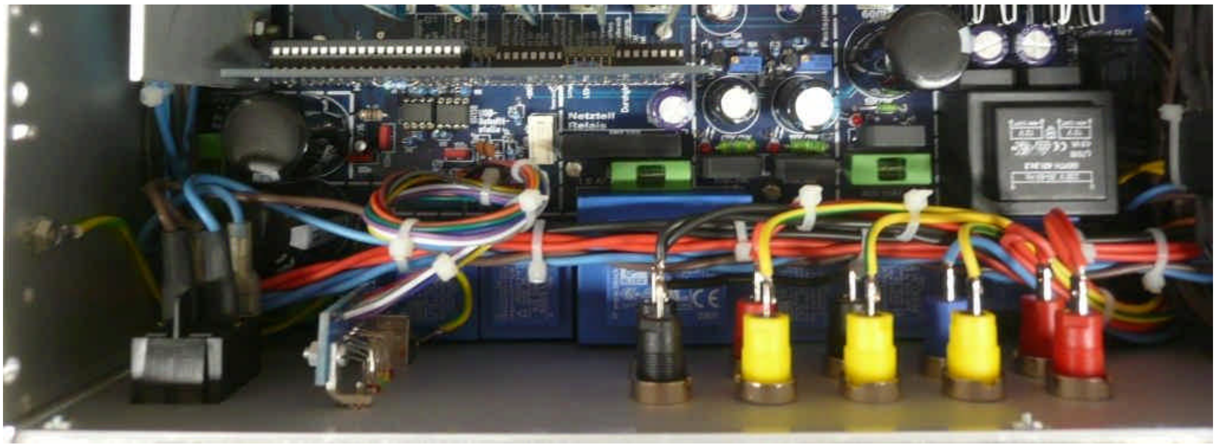
The 19"-concept requires several cable sets, to distribute the signals within the system and towards the front- and back panel:

- USB-Interface 10 signals to the front panel
- Transformer 12 power signals and ac wiring internal 1mm²
- Tube-Box-Adapter 10 power signals + grounding 1mm² to the front panel
- Experimental Plugs for all voltages 8 power signals 1mm²/2mm² to the front panel

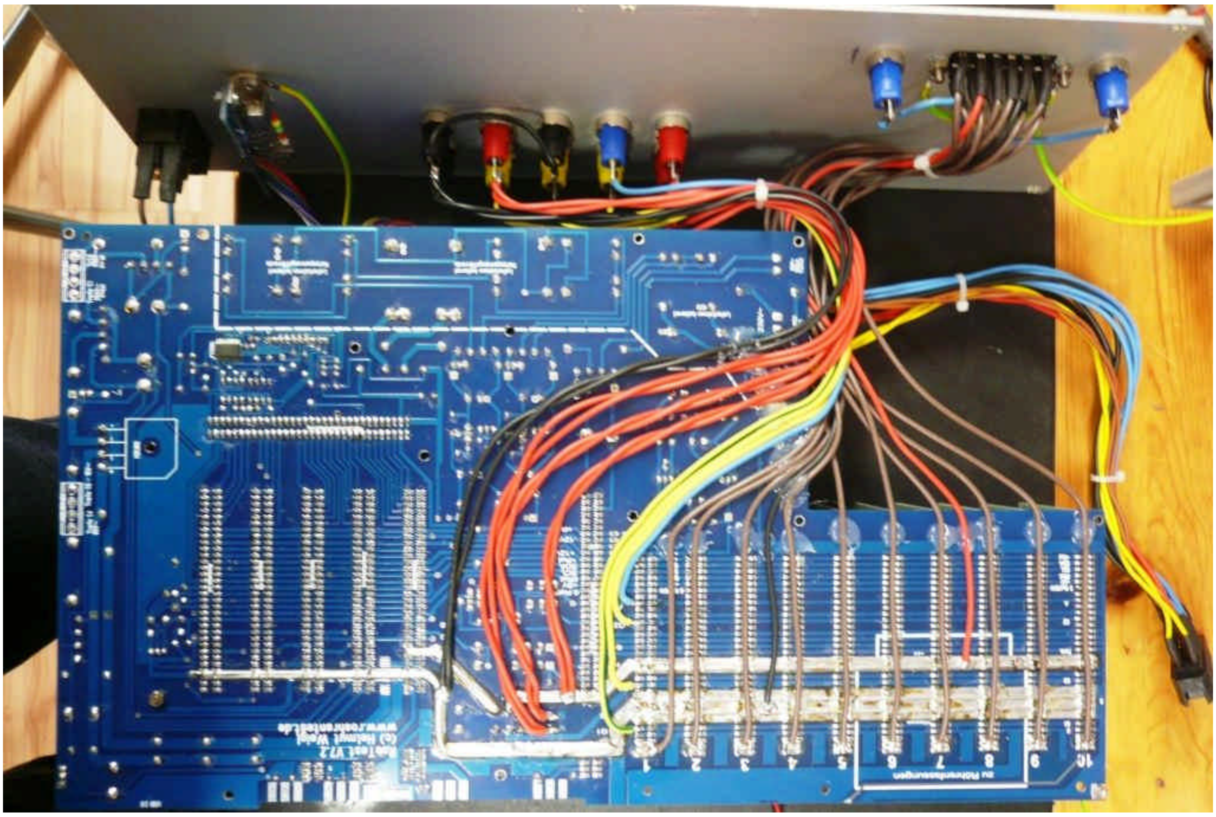
I used the 12-pin power connectors to contact the transformer, so that the whole electronics can be operated outside the 19"-carrier, for example for test- and repair activities as shown above. All transformer signals are soldered directly to the main pcb to avoid the weak connection terminals.



The usb-signals and the experimental plugs look like follows:



On the bottom side of the main pcb the wires for all tube signals are directly soldered to the board, fixed by hot-melt adhesive and then led to the front panel like this:



It took me about 35 hours to produce and integrate the cabling of the system. At this point the additional efforts for a system differing from the original design are heavily increased as well as for all the mechanical adaptions. The original design with the front panel as system carrier can be rebuilt much faster and more efficiently, also as it does not need these cable trees.

Development of the front panel:

My system cannot use the perfectly prepared original front panel design. Therefore I decided to build the front panel on my own and not to use the proposed supplier Schaeffler (German front panel supplier). Some time ago I found some interesting hints in the internet, how this can be done easily for a small number of pieces. This is what those people described:

- Develop front design in your PC, for example using the drawing functionality of word
- For front panel bigger than A4 => split design into several pages
- Print design to good quality paper, for example with cheap ink-jet printer
- Laminate printed pages with simple office hot laminator on both sides (80m foil)
- Cut laminates to format of front panel
- Cut border between designs by putting them on each other and use cutter
- Process front panel by usual mechanical steps
- Glue laminates carefully onto front panel at correct position
- Cut out openings in the front panel by cutter carefully
- Small openings can be cut out as a block (here LEDs)
- Assemble all front components to front panel
- Ready is a pretty front panel, if required including nice pictures on it

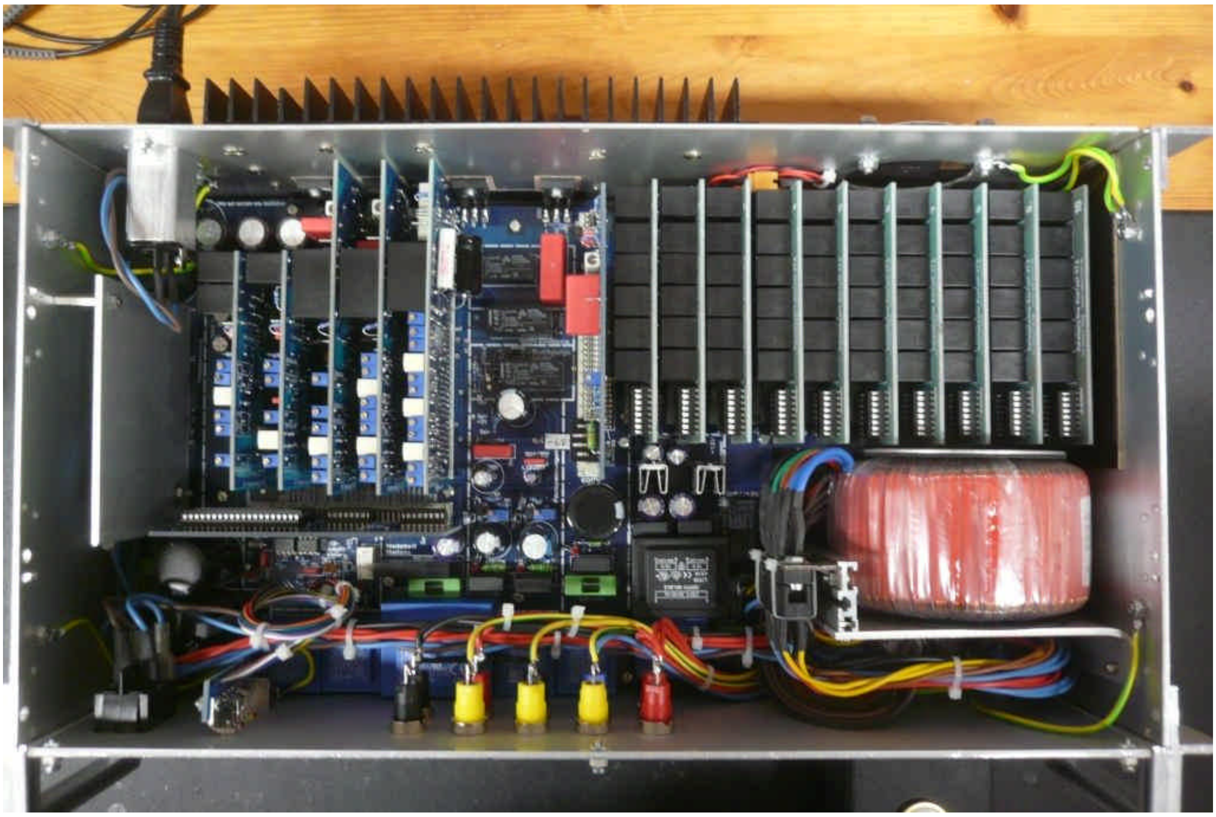
This is what I did, it worked pretty fine and looks great after about 10 hours of work, much better as with the use of these expensive special foils offered for industrial applications. This is really nice! Compared to a professional front panel you should not count your working hours but the result can easily be reworked if required. In my case I had to do it a second time as I wrote the inventor of the system Mr. Weigl as „Mr. Weigel“ in a wrong way … so another 5 hours for a new front foil went by.

The second front panel out of the PC in a more detailed view including the picture of one of my favorite tubes, the KT88:

Here you can also see the experimental plugs for tube experiments using the system as a high end luxury power supply. This works extremely good with this system as you can control and watch all the voltages and currents in manual mode. And everything is perfectly protected then. I love it!

The 19“ system first shot:

After all the described work steps the system can now be integrated and looks like this, after the cable trees have been focused by cable binders:



Calibration and Test with tubes:

The first look into the handbook concerning calibration of the system seems to be confusing. The calibration is described in details but the logic behind the procedure is not immediately clear. But the simple way to understand the calibration is just to do it step by step following the handbook. After the first steps everything becomes pretty clear and works fine. It is really simple.

My first calibration took about 6 hours, as I had to prepare the load resistors for the current calibration first. Several high power loads have to be prepared to allow the current calibration. Everything worked fine. Just a 1k trimmer on the G1-card had to be increased to 2k to achieve the full adjustment range (low voltage range upper limit).

The calibration is precise and very stable, also after several hours of operation and several days of system standby, exactly as performed during the initial calibration, no deviations even until today.

Finally after the first raw tests of several tubes I could start the calibrated test runs on 12/31/2014. The following tubes have been tested on the system still in 2014:

EF80/ECC82/ECC83/KT88/KT90/KT120/KT150

RoeTest and temperature:

Until the power pentode KT120 the RoeTest system worked pretty good, but an increasing temperature could be observed. The high power tube KT150 drove the system temperature at the thermal sensor so fast up, that even after an increased parameter for temperature limit the system shut down several times. Permanent operation with such a tube was not possible.

The KT150 has a limit of 70W anode power dissipation and typically runs at 400V Va with 180mA Ia, 6,3V Vh with 2A Ih heater current, 225V Vg2 with 10mA Ig2. Within RoeTest this leads at least to the following power losses roughly calculated:

- Anode 350V-100V = 250V x 0,18A = 45W
- 600V voltage increase 350V-300V = 50V x 0,18A = 9W
- heater 18,5V-6,3V = 12,2V x 2A = 24,4W
- grid 2 350V-225V = 125V x 0,01A = 1,25W

For continuous operation of the KT150 the cooler temperature ran up to critical 70°C. A cautious calculation of the semiconductor temperature shows:

- Rth semiconductor => package 0,45K/W
- Rth package => cooler surface 0,24K/W
- Rth cooler surface => kapton foil/cooler 0,15K/W
- Rth overall semiconductor => cooler 0,45+0,24+0,15 = 0,84K/W
- At peak power of 60W losses => 50,4K temperature semiconductor above cooler with 70°C
- Peak temperature of semiconductor > 120,4°C

I contacted Helmut Weigl and he showed me his temperatures profiles of the system during the development phase, and all his measurements stayed well below 50°C of the cooler. The original design used a heavy 5-6mms aluminum front panel and an additional cooler on top with only 0.45K/W. This concept allows a lot higher power output of the system than my 19"-system.

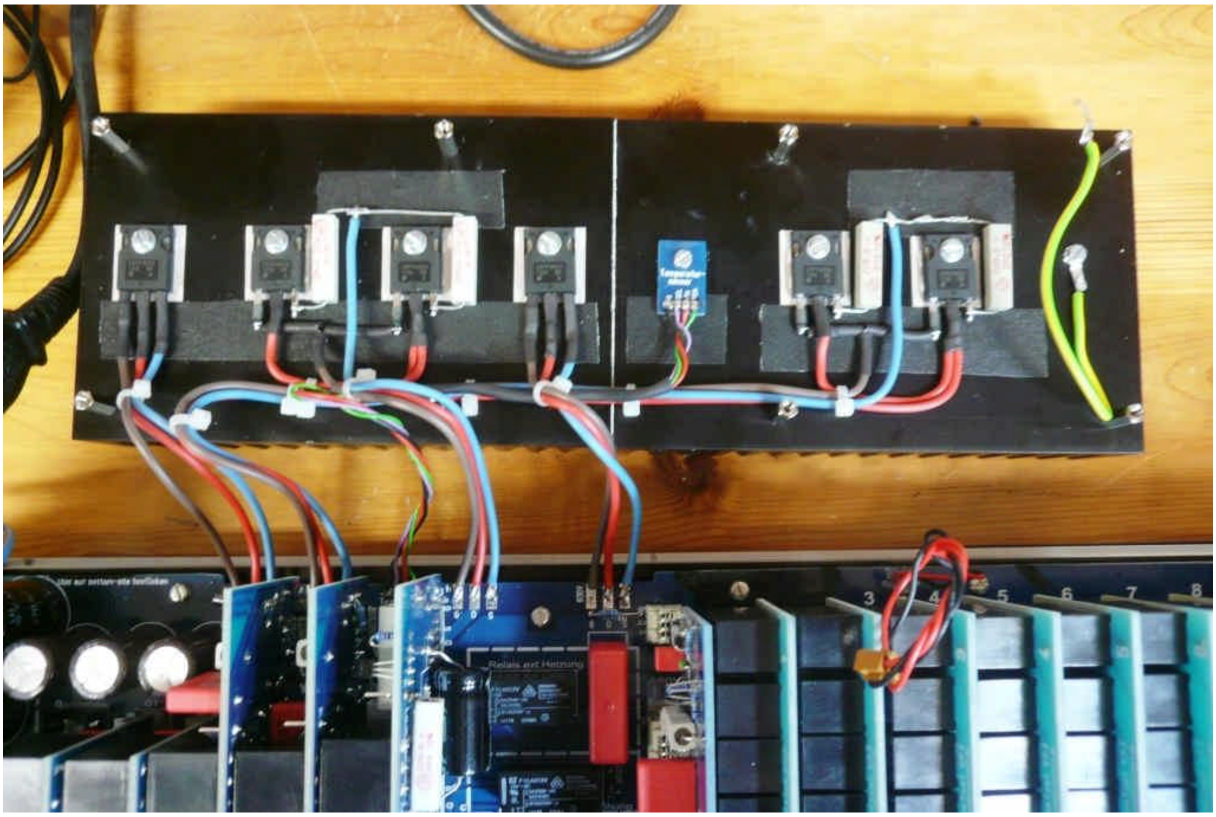
Helmut proposed to use an enhanced cooler for my system. As I'm interested to use power tubes in permanent operation (only this allows stable values with thermally stabilized tube) I decided to replace my existing back panel and cooler with a more powerful solution.

Important for me was the chance to use the system also for even bigger tubes up to the limits of RoeTest without any thermal limitation. The transistors in heater- and anode-regulator have to take over up to 100W power losses depending on the working point of the tested tube. This leads to 100W x 0,84K/W = 84K temperature above the cooler temperature. Therefore I decided to split this power stream into 2 transistors for heater- and anode-regulator to achieve the best possible support of the used cooler unit.

The parallel operation of 2 power mosfets within a regulating loop only leads to a 50/50 power distribution and stable operation without oscillations if some tricks are used:

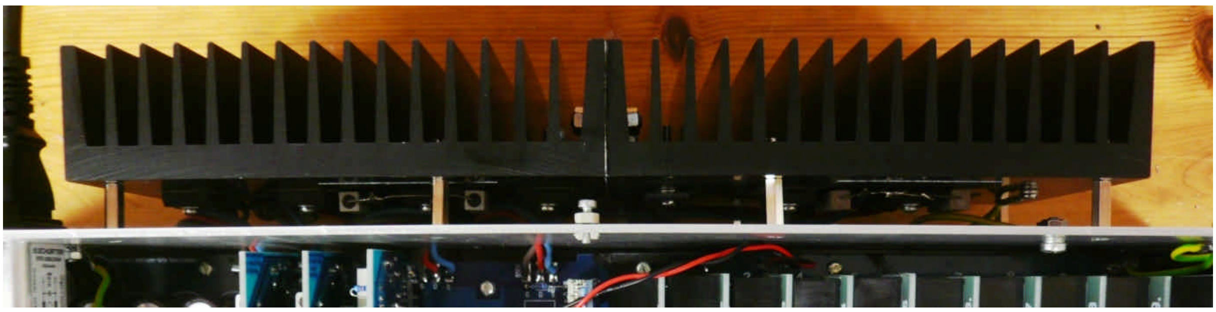
- The gates have to be coupled over 470R resistors, not directly
    - If not done this way, the parallel transistors can get into oscillations
- The transistors have to be selected for minimum threshold difference Vgs
    - Differences of Vgs threshold should be < 20-40mV
- The sources of the transistor should contain series resistors for enhanced symmetry
    - This reduces remaining asymmetry of power stream

Then I used two cooling blocks behind the back panel (outside of the housing) with each 0.9K/W, which are connected by heavy bolts. The resulting unit looks like this now:



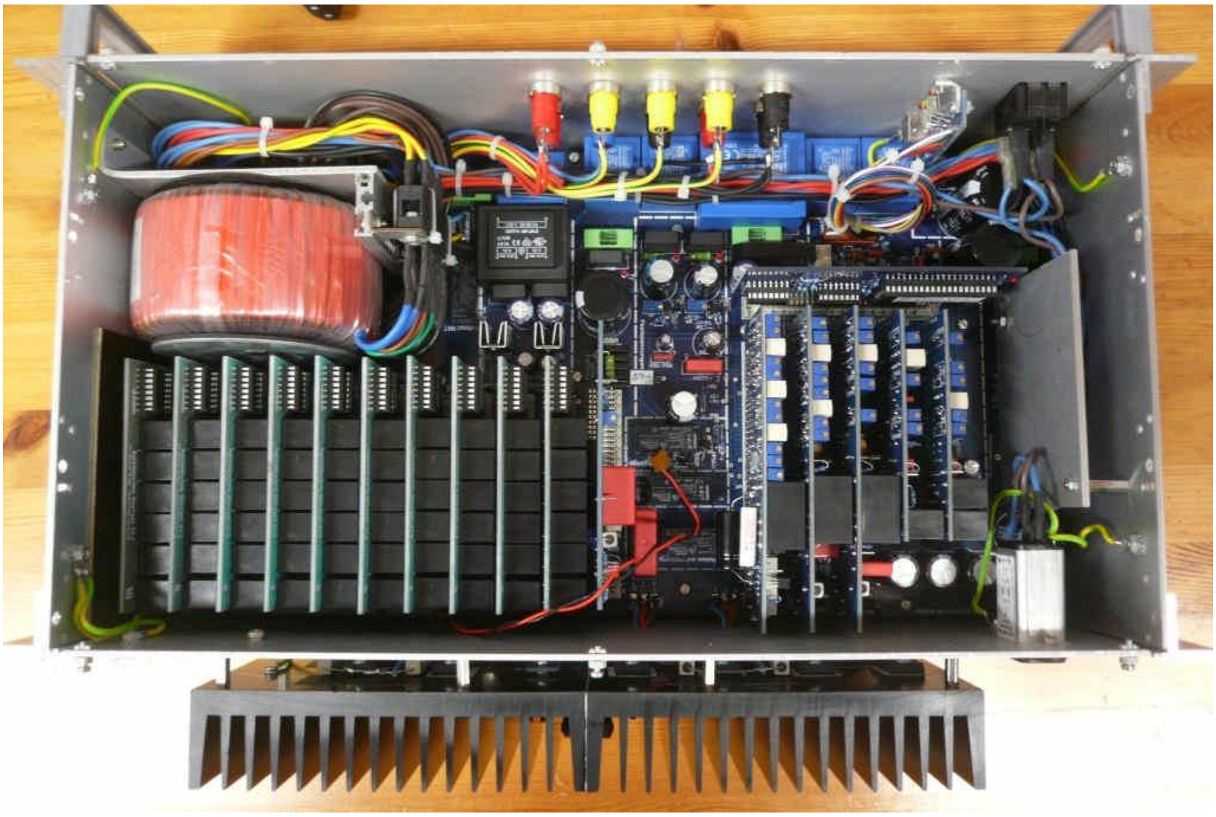
From the left to the right we now have: G2, Heater1, Heater2, 600V, T-Sensor, Anode1, Anode2

The transistors have source series resistors of 0.22R for the heater circuit, 2.2R for the anode circuit. All gates are connected to the driver signals via 470R resistors. The anode circuit is now up to 25cm longs but it stays perfectly stable under all circumstances. The transistors could be selected for a Vgs difference of only < 10mV. The power distribution is now +/-4% for the heater circuit and +/- 3% for the anode circuit, perfect.



The 19“ system second shot:

With the intensive rework of the back panel the fan also was relocated to the top cover of the housing, where it takes the heat of the regulator cards out of the system (the power resistors of the regulator cards also deliver some heat). The whole reworked system is shown in the following picture:



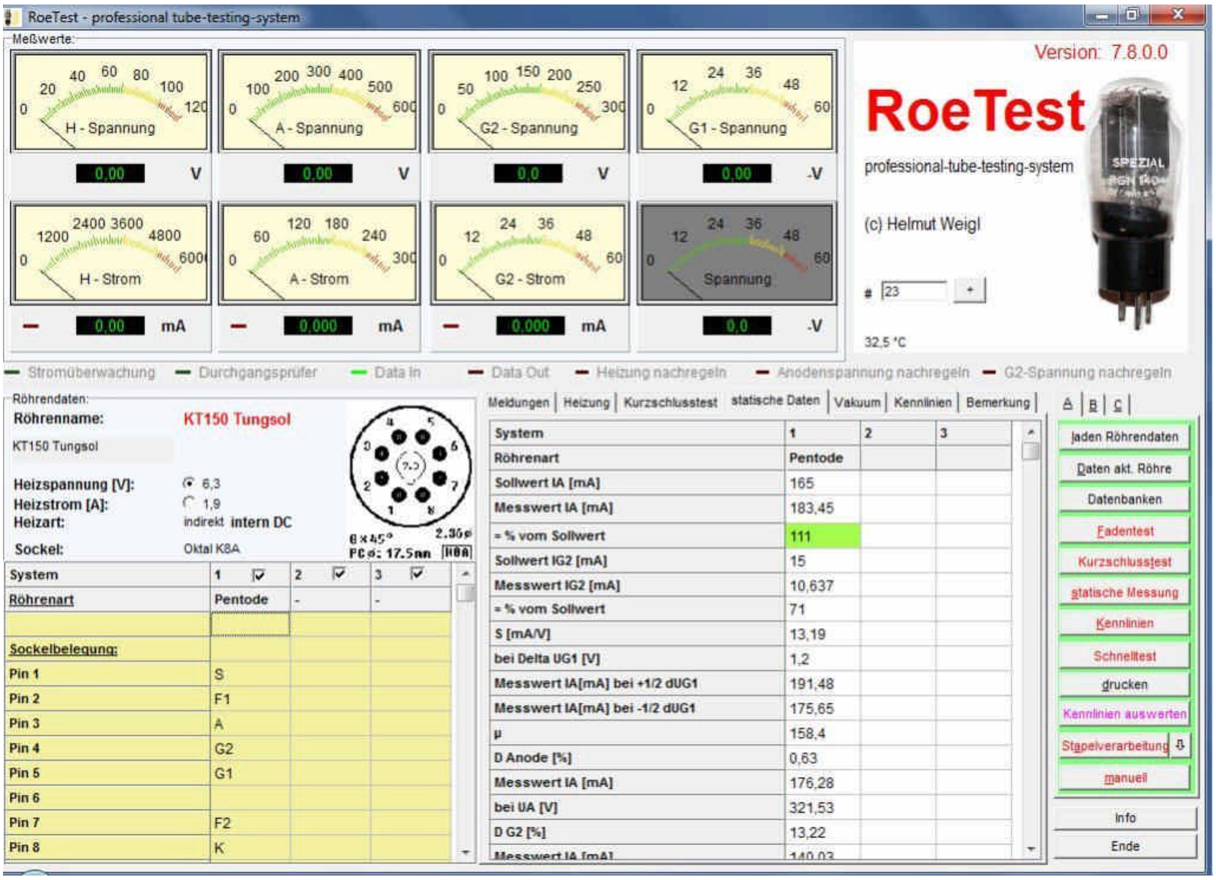
The system went through a complete recalibration procedure, but the modifications had only a quite small impact on the calibration. In addition during the test measurements with selected tubes all tube voltages where checked with an oscilloscope (Gate 1/2/3, Anode, Heater). All signals show soft regulation steps during change of output voltages, a stable turn-on and turn-off behavior and an absolute stable characteristic during test steps without any oscillations.

For times, where the tube outputs are deactivated, a small 50Hz noise can be seen at the floating tube pins, which is caused by a high impedance coupling of the transformer into the tube wires to the front panel (those wires get quite close to the transformer there). As soon as a test cycle starts and the regulators start to drive the tube pins, the noise level breaks down to only 2-3mV remaining 50Hz noise which is insignificant. This also has no impact on the measurement results, which are stable down to the last digitizing step.

A KT150 tube in permanent operation - also for increased anode power (limiting values already exceeded) - heats up the system at the cooler after 2 hours to a temperature of friendly 52°C. Now the system has enough power reserves to handle even bigger tubes without thermal problems.

RoeTest Overall:

The completed marvel of technology (system including closed housing and control PC) looks like this:



In many repeated single test cycles I tried to evaluate the reproducibility of the test results. Repeating tests with the very same tube for many times are only influenced by one parameter: the preheat time. Using different preheat times can change the test result by 5-10% (old tube designers experience).

As soon as a tube is baked-out completely and had enough time to thermally stabilize (takes up to 30 minutes for big KT150 tube) the measurement results off different test cycles differ only by just 0.5%, in many cases the difference is in a range of only +/- 0.2-0.3%. This result is extremely precise and exceeds my highest expectance by far. Even burn-in effects during the first 24 operating hours of a tube show much higher differences. This is a perfect technical performance, especially for a system, which is used to characterize tubes by matching them in several working points.

Limits of RoeTest:

Naturally even a marvel of technology as the RoeTest has its limits. One limit is the anode voltage of up to 600V. For audio applications there are several tubes like the old 211 and 845, which have typical anode voltages in their working points of about 1.000V. These tubes can also be tested by the RoeTest, but only quite far away from their typical operating conditions. It is easy to understand this limit as such an anode voltage would require a much more sophisticated isolation within the system to handle 1000-1200V safely. Several additional regulator cards would also be required for the grid voltages to address this extended voltage range.

Also the latest RoeTest hardware stays below the required isolation level requested by regulatory requirements concerning isolation and handling of high voltages. For example the signal plugs, connectors and relays are not accredited for the used voltages of up to 600V. The air- and creep distances inside the system would have to be enhanced for the regulatory requirements. The whole system would be a lot more expensive and bigger in size to fulfil all requirements.

But the system based on the latest hardware works pretty good and stable, only a careful grounding of all touchable parts should be done to ensure safe operation. The latest regulatory requirements would be clearly excessive from a pure technical point of view (see also old tube equipment as old radios which would have no chance to achieve today’s regulatory certifications or even a CE mark).

Overall efforts for building my RoeTest 19“:

For the production of my RoeTest I spent about 1.200€ material costs, also because I had to rework some already finished parts (thermal problem).

My worktime of about 160 hours was required for the following steps:

- Electronics assembly, size reduction pcb, rework to V8: 35h
- Calibration and production of load resistors: 9h
- Mechanical carriers, back and front panels, final assembly: 78h
- Cables of the system: 35h
- Reports: 3h
- **Overall efforts over about 3 month: 160h**

Personal conclusion for my RoeTest 19“:

Lessons learned by building my RoeTest?

The moral of the story is, don’t use a too small housing!
Is is not a big deal to build a 19“-version of RoeTest, but the housing should be big enough for the system to fit in an easy way. The housing should have a depth of about 300-350mms and not only 240mms as my case. This saves a lot of time, which I had to spend for mechanical extreme work due to my cost effective housing.

RoeTest as rebuild project:

Who decides to do a rebuild project or to use a kit, depends solely on the inventor. And in the case of Helmut Weigl you are in the best possible hands. He did not avoid any effort (and he must have used thousands of his working hours!), to achieve an affordable and easy to build tube tester. Even if you make mistakes during your project, he helps you quickly, engaged and immediately to solve your problems. As good as ever possible! The rebuild project RoeTest is a dream. Someone, who fell in love with tubes, should not be forced to live without a RoeTest (basic right of tube friends?)

During the last 30 years of using kits and rebuilding things others invented I never ever had a project, getting even close to this. It was so satisfying, worked perfectly fine and is worth every cent I spent.

RoeTest my system:

I spent 160 happy hours of my life for building my RoeTest and I am really excited about the results (and I usually hate mechanical work). All my expectations have been exceeded by far. Today, if I come home after a nonsensical work day in the world of semiconductors and my RoeTest starts to clicker softly doing its precise measurements, the day finally still becomes a good day. I’m sure, there will be a lot of nice audio amplifier projects follow this project, using tubes selected and characterized by my RoeTest.

I’m happily looking forward to the next month of exploring all the other fascinating functionalities of my RoeTest and its powerful software. This is even more than having Christmas for a small boy, or not?

Thanksgiving:

Thank you Helmut, for that you invented and optimized this great system with so many personal efforts for so many other people. And thank you, for that there are still people like you even nowadays, who not only are aiming at profit from their efforts but just share the results with others. This is for sure no longer naturally in these days.

At this point I would also like to thank my brave girlfriend for her patience and understanding during these last 3 month, as she had almost nothing to expect from me, while I was allowed to build this RoeTest. To plug in the electronic cards also was fun for her and she seemed to enjoy it (it also worked fine!).