Some notes on repairing
Tektronix 7603 etc. power supply

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Table of content

Introduction

Content

In May 2022, I went to a electronic fair and bought for few euros some Tektronix mainframes and some plug-ins, starting a new exciting activity that went perhaps my original intentions.

My first buy at the fair

I decided to write these few notes to help others to repair and restore these wonderful instruments.

I consider myself a senior electronic engineer (even too much senior…), but I was completely new to the world of Tektronix and transistor-based analog technology. So, forgive me for any mistake or wrong information herein contained, and possibly help me to correct.

If you like Tektronix oscilloscopes and other old electronic stuff, you can download for free my 200+ pages booklet from http://www.k100.biz/parade.htm

Repairing 7603 (and similar) power supply

Content

Here we report some note of my repairs I did on the power supply section of the following Tektronix models:

- 7603;
- 7623A;
- 7633;
- 7403;
- OS-245(P)/U, aka 7603N-11.

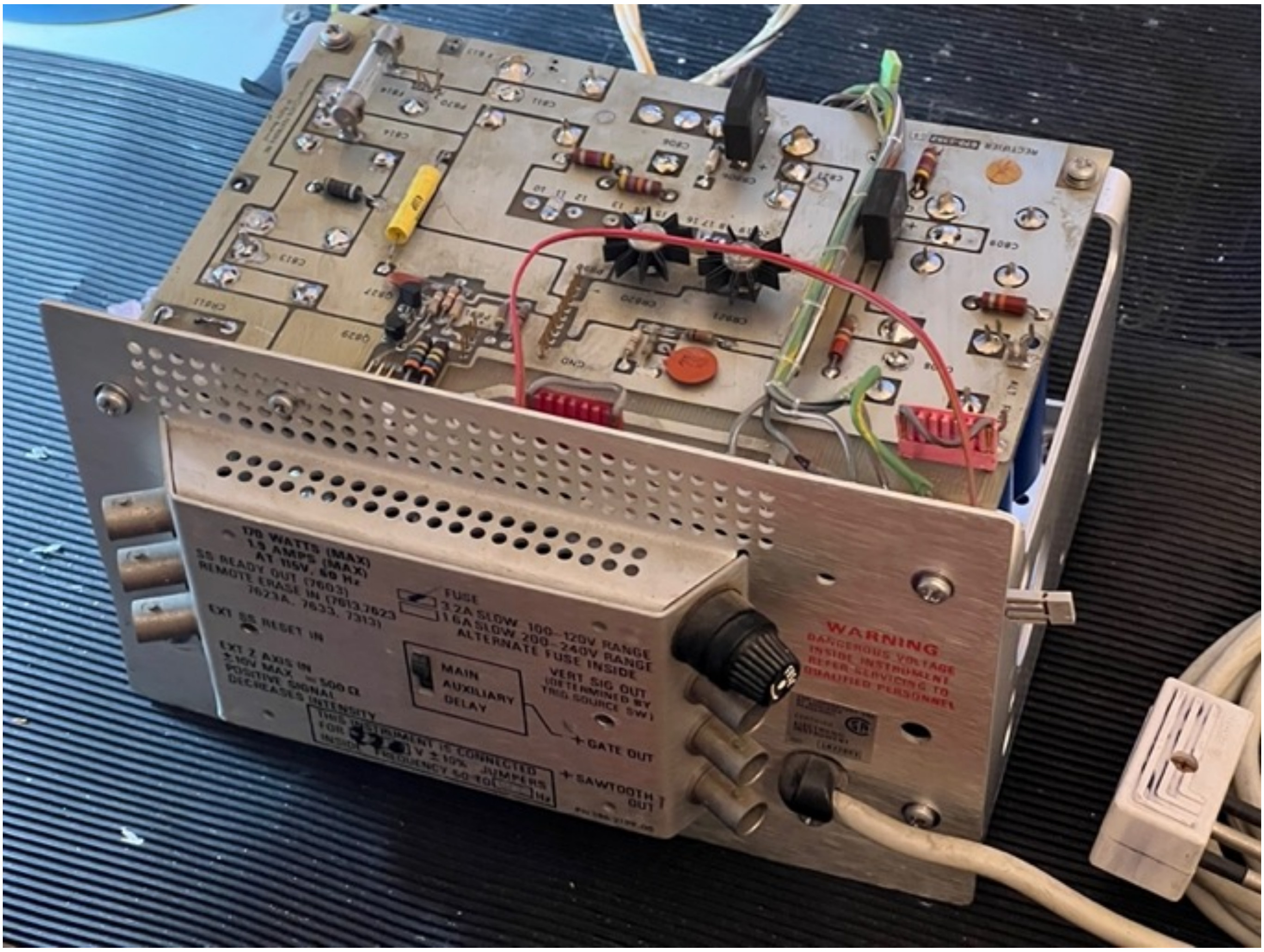
Maybe that they can also be applied to similar models, as 7613, 7623 etc.

The power supply section is composed by two modules:

- **A10, rectifier board,** mounted on the transformer assembly.
- **A11, low voltage regulator board**.

Documentation

The Tektronix manual 070-1429 is well done and its explanations are rather clear. On TekWiki, you can also find the redrawn electric diagram, easier to read that the original one in the manual.



The transformer assembly with the A10 / rectifier board

The A11 low voltage (LV) regulator board

Removing the transformer assembly

To removing the transformer assembly, you have only to remove four screws, but you must be very careful because there are many cables that connect to various parts of the equipment and furthermore there are the cables that pass through it to reach the rear panel **A12 signal outputs board**, linked to the BNC connectors. Those cables do not interact with the power supply, and if you are going to service the PS, you can disconnect and forget them. If you like as I do to work comfortably, you will remove it completely. To do that, you have to remove also the connections from the power switch.

Caution

I recommend you something that seems completely obvious, but it could come the time that you forget that, so be very, very careful:

- **connectors:** flat cables were novelties at that time and had connectors not yet polarized/driven. That means that you can mount the connector in 1) the right way; 2) 180°-turned; 3) shifted by one or more places on the left or on the right. All the solutions but 1 are catastrophic. You will say: it is obvious, I am not so stupid, it cannot happen to me. Good for you.
- **photos**: when you dismount, it seems easy to remember where the connectors were mounted. When you will go to remount them, you realize you forgot everything. So: take photos of every connector you detach. The general wiring schematic (see pag. 13) can be a help, however.
- **sockets**; all the transistors and the ICs are mounted on almost invisible sockets. Be careful and treat them well. They can be still today rather reliable but are very delicate.

The circuit

If you look at the circuit, it seems rather complicate, also because is composed by many sections, one for each the voltages we must produce: +50V, -50V, +15V, -15V, +5V, +130V. I could not understand why they didn't make each section independent. Each of them uses, in some way, the others, so debugging is very difficult. The only reason I can imagine is that they wanted to have just on trimmer to tune, to adjust at the some time all the voltages. Let's try to understand how those circuits work.

Sense feedback. As any stabilized power supply, this circuit operates as a closed loop, to adjust the output voltage as a function of the load changes, here we have a difference: instead of reading the voltage at the output of the regulator circuit, we have a separated wire to read it at destination, compensating the voltage drop on the main supply wire. I report the figure from the manual that explains this concept. Note however that this kind of approach is used only toward the main interface board, perhaps to compensate the differences in the plug-in absorption, whilst the largest part of the internal circuits doesn't use this feature.

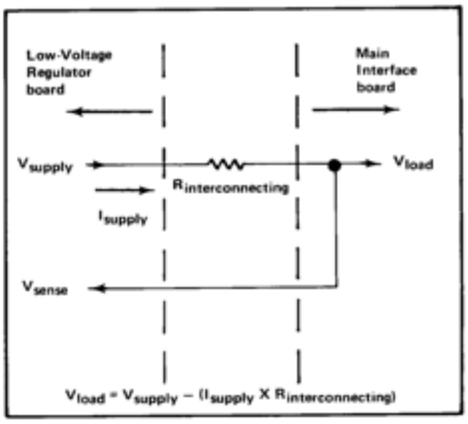
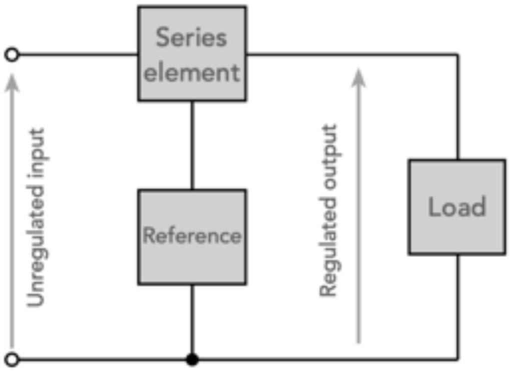


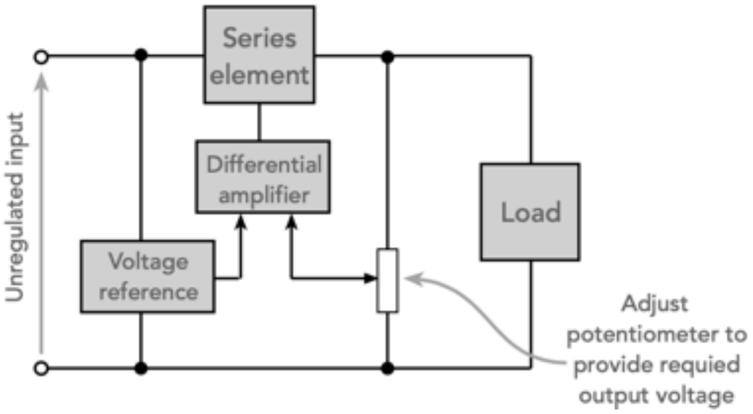
Fig. 4-23. Schematic illustrating voltage drop between power supply output and load due to resistance of interconnecting wire.

Basic circuit operation. This is a basic series regulator circuit:

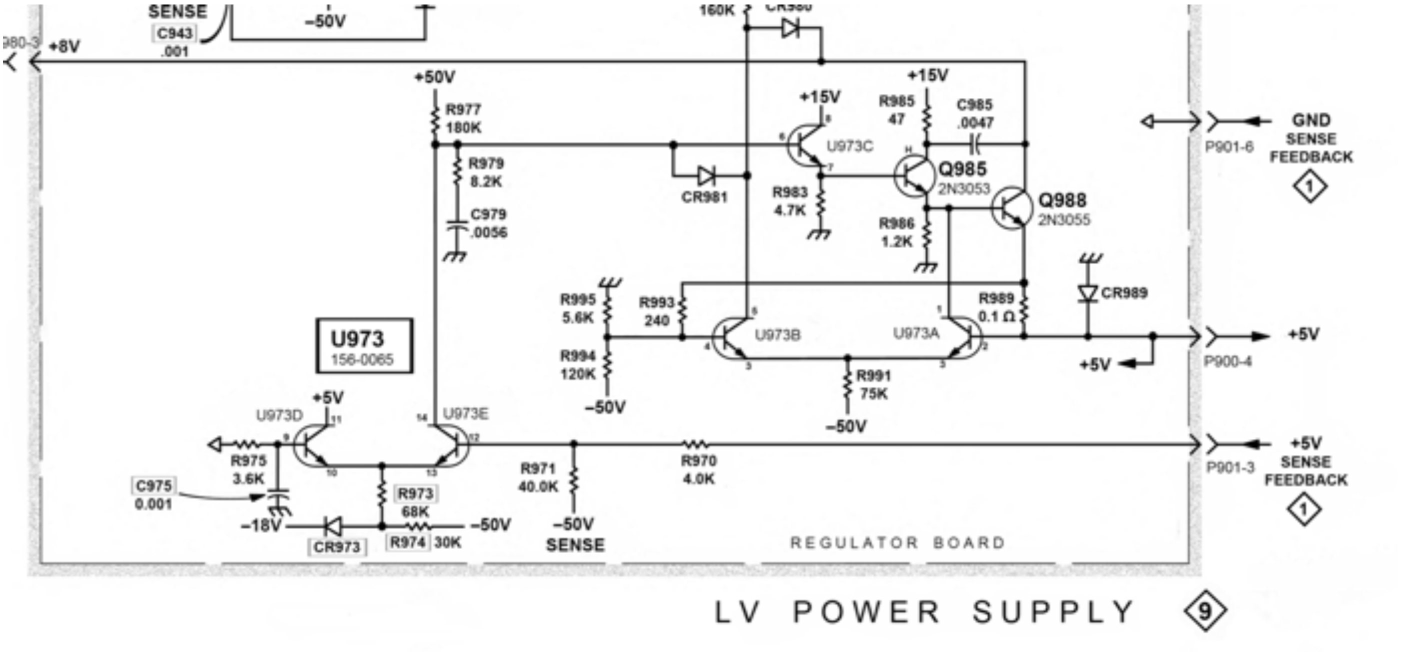


The input voltage is always higher than the desired input and the current toward the load is the same. But, as you know, the power is given by the product of the voltage times the current. For example, we could have: Vin = 15V, Vout = 5V, I = 1A. We have 15W (15 x 1) in input and 5W in output (5 x 1). And where did they go the 10W difference? Simple: it goes in heat, normally dissipated by the Series element. For this reasons, power supplies circuits like the 7000-Series are today rarely used, preferring switching regulators that operate on a completely different principle, much better from the energy point of view, but that could also produce some unwanted electrical noise, not welcome on an instrument like this.

Coming back to our case, the 7000 PS follows this scheme:



The potentiometer is present only on -50V, the other voltages are in someway linked to it, as we noted before. We will see now, how this scheme is realized in the 7603 PS. We will analyze the +5V section, that is rather simple (following figure).



Voltage reference and differential amplifier.

- Input: the SENSE FEEDBACK from the +5V rectifier/filter board
- Output: the voltage reference, collector of U973E (pin 14).

U973D and U973E compose a very simple differential amplifier that decides the output voltage. The left branch read the reference voltage, 0V thru R975, while the right transistor is connected to the sense feedback of the stabilized +5V. If you calculate the voltage divider composed by R970 and R971, you can see that base of U973E stays at 5V. In fact, 55V x 40,000 / (4,000+40,000) = 50, relative to -50V, so practically 0V. Thus, the output of the differential amplifier (collector of U973E) is at +5V when the other voltages are at their nominal value.

Series element. The series element is Q988, but it cannot be driven directly by the output of the differential amplifier, so U973C and Q985 are required to amplify the required current. U973C, Q985 and Q988 constitute thus an amplifying chain of cathode followers. Each of them has a voltage gain of 1, but amplifies the current. The small resistance on the Q985 collector has probably only the purpose to limit the current. The final transistor Q988 has not an emitter resistor, like the others, because its load are… the oscilloscope circuits it feeds!

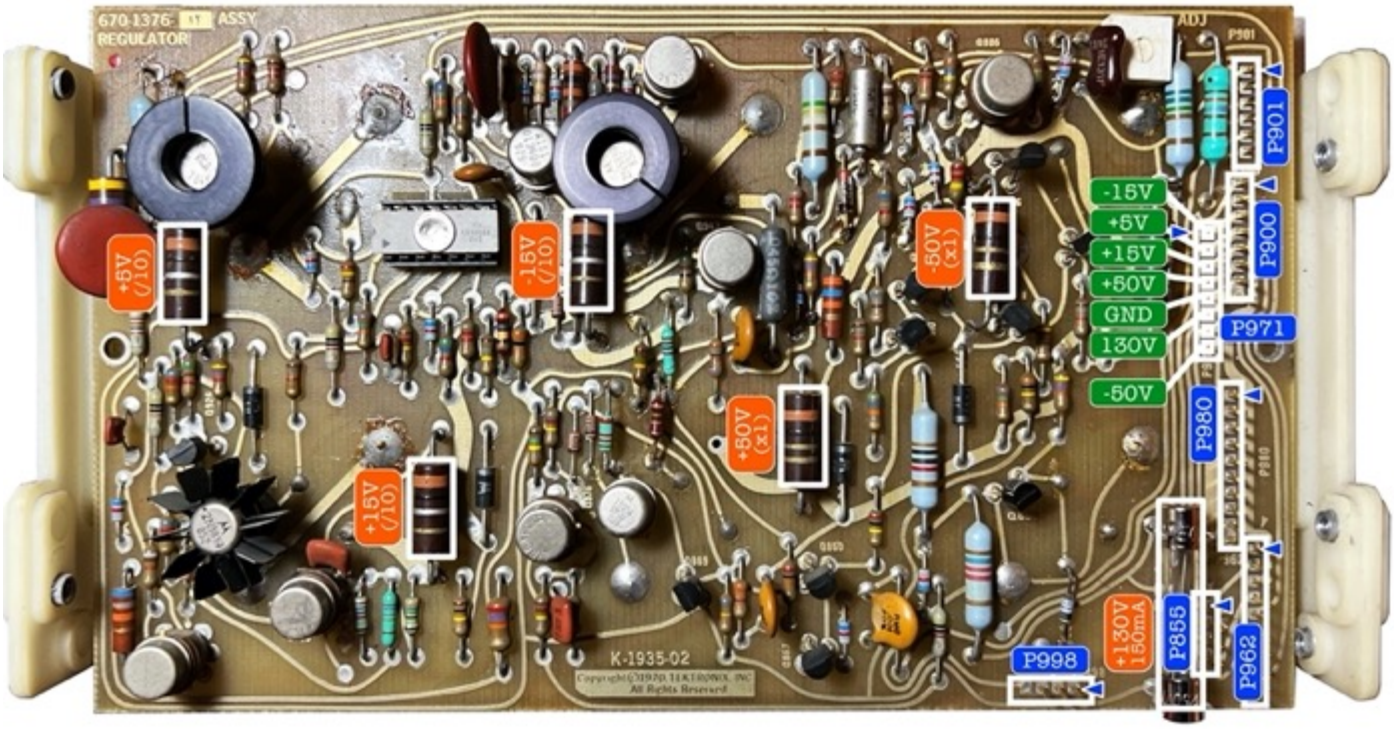
Regulation. If the load sinks more current, the +5V SENSE CURRENT decreases, and so U973E conduce less, increasing the voltage at its collector and thus at the base of U973C, and, in consequence, at the base of Q985 and Q988, and thus to the load. Similarly, and opposite when the load decreases. Note that the regulation is performed also when the supply voltage changes.

Overload protection. The circuit is protected in the case of an overload on the output. This task is performed by adding a very small resistor in series to the load (0.1ohm, in this case), that do not alter the main current flow but that allows to measure the voltage drop at its terminals and understand if a too high current is flowing. We find here again the same comparator circuit that we saw for the voltage reference, composed by U973B and U973A. The two input to the comparator are the transistor bases, that are placed across the 0.1ohm R989 resistor. When the difference between them exceeds a certain value, U973C starts conducing and set negative the base of Q988, limiting the current.

+130V supply. The circuit for this voltage is different. There is not a transformer secondary for this voltage. The transformer delivers about 80V. They are “summed” with +50V by mean of Q850 and regulated by Q852. Furthermore, there is no current protection circuit but just a fuse (F855).

Measuring the currents. The resistors designed to be part of the overload protection, can also be used as a simple mean to measure the current of each voltage. Just measure the voltage across them. For +50 and -50, the read value is the current value. For +15, -15 and +5V, you must divide the read value by ten (e.g., if you read 1V, the current is 100mA.

The following picture helps you in that: you can see the resistors where measure the current and the points where measure the voltages. For the currents, it is reported if you have to divide the read value.



Dummy load. I tried to create a dummy load for each voltage, so that I could test the board without connecting to the scope. I did not succeed. Perhaps, considered the voltage interdependences, the load must be exactly as the real device and mine was not. In any case, don’t forget to connect to the load also the sense input for each voltage.

First power-on approach

In the case of an old scope that you try to power-up for the first time, different strategies are possible. I just list the one that I am following currently.

- **Line voltage.** Check the line voltage. Some scopes travelled from the States to Europe, so don’t assume that the setting is correct for your country.
- **Fuses.** Check the fuses. If they are blown, a different approach is required.
- **Plug-ins.** Remove all the plug-ins from the scope.
- **Disconnect secondary circuits.** It is useless to stress also the circuits that are not immediately useful. Disconnect from LV board the following connectors: P971, P998, P981 and P962.
- **Disconnect the HV board.** It is better to have not to deal with the possible HV problems. Detach P1130 from the A8 Z-Axis amplifier board. Explanation: the A9 High Voltage board, that generates the 7.5kV voltage for the CRT, is powered by the **+15V UNREG**. This line starts directly from the A10 rectifier board (transformer assembly), thru the A8 Z-Axis board. The +15V UNREG is passed as follows:

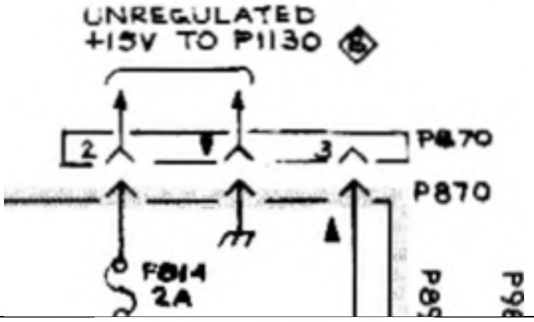
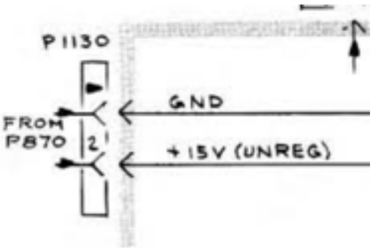
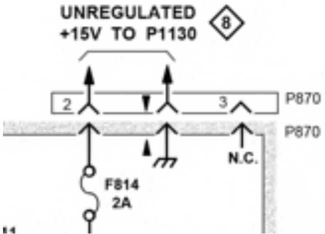
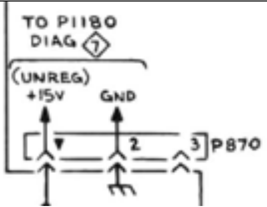
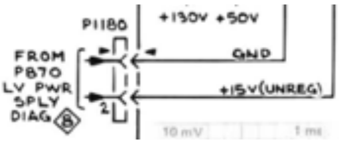
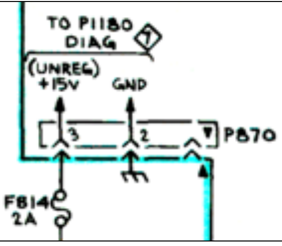
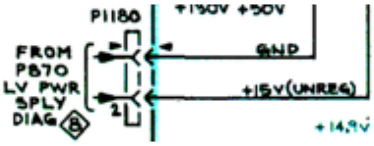
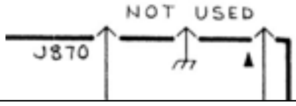
  A10 rectifier board, P870 → A8 Z-Axis board, P1130;

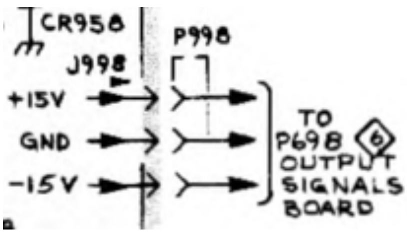
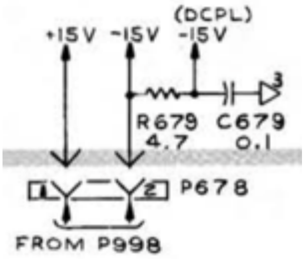
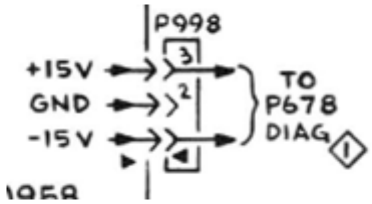
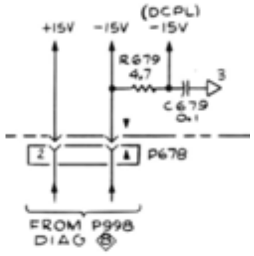
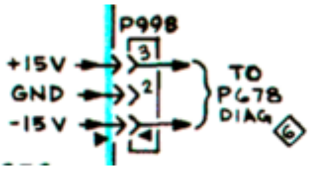
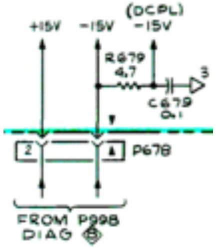
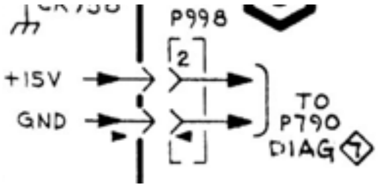
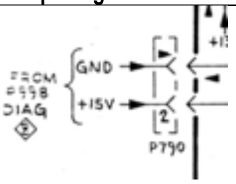
A8 Z-Axis board, P1120; → A9 HV board, P1220.

Note 1. Pay attention that P870/P1130 are a little tricky (see the table below with the connector schematics):

- P870 has 3 pins, whilst P1130 has two; the cable has 2 wires;
- the schematic in the 7603 manual could be rather confusing, because pin 1 of the cable has been drawn on the pin 2 on the PCB;
- the file "Tek_7603_power_supply_A10_and_A11_schematic_(redrawn)" that you can download from TekWiki contains an error on pin 1 of P870 marking;
- I report also the 7623A and 7633 schematics that are clearer.
- Substantially, you have to connect P1130 pin 1 to GND and P1130 pin 2 to +15V.

Note 2. In the OS-245(P)/U (the so said military version of 7603), the output signals board is not present and the HV board is powered by the regulated +15V, taken from P998 on the LV board.

	From P870 on rectifier board	To
7603		 To Z-axis amplifier
7603		**← Wrong pin 1 indication in the file** **Tek_7603_power_supply_A10_and_A11_schematic_(redrawn)**
7623A		 To Z-axis amplifier
7633		 To Z-axis amplifier
OS-245(P)/U		**Not used**

	From P998 on LV board	To
7603		 To output signals board
7623A		 To output signals board
7633		 To output signals board
OS-245(P)/U		 To Z-axis amplifier

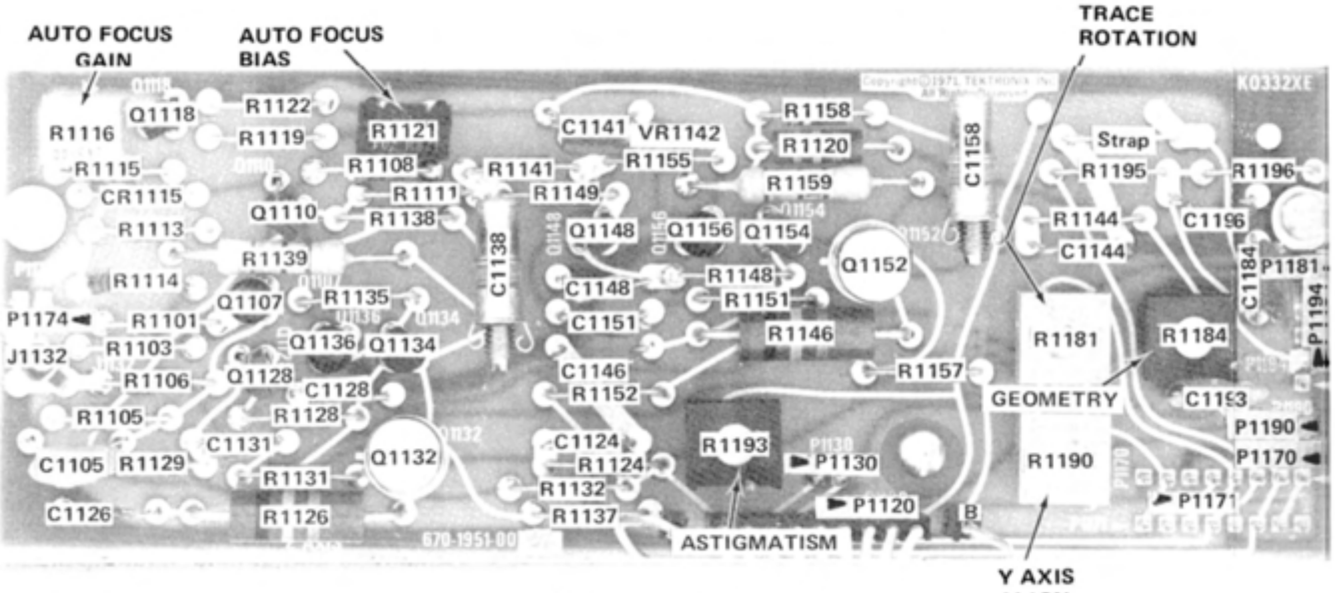


Fig. 8-10. A8. Z-Axis Amplifier circuit board.

- **Voltage check.** A good point to measure voltages in on the horizontal amplifier. Connect the VOM between -50V and ground and briefly switch on the equipment. Operate in a quiet room and listen carefully for any sound, that can help you to detect a possible problem.

- **Checking other voltages.** If nothing exploded or smoked, you are a step forward. If the voltage is OK or almost OK, you are two steps forward and can continue checking the other voltages.

Wrong voltages, what can I do?

If one or more voltages are wrong, I suggest you stop and remove the transformer module. It is highly probable that one or more electrolytic filter capacitors are no longer good. As we said, it is rather simple. See "Removing transformer assembly". When dismounted, place it on your workbench and start checking it. Don't worry if the voltages are higher than reported by the schematic. It is normal, being them unregulated and without the load.

If you have a capacimeter, use it to verify the capacity of the big electrolytic capacitors. It should be about the nominal one or bigger. If you have not the capacimeter, you can check the voltage on the filter with the oscilloscope. If it is pulsating instead of pure DC, you need to replace the related capacitor. Follow the schematic, it's rather easy.

If the capacitors are good, the problem is likely in the LV board (see below).

Replacing the big electrolytic capacitors

Don't try to unsolder them, it's wasted time. They are big and heavy, and, even if you have a solder large enough, it's likely you will damage the PCB. I found the best way is sawing them away with a strange tool that I received for free buying a battery drill, simply called "multifunction tool". It is a motor that makes a blade saw to oscillate at high speed (see picture). Mine is from Makita, but almost any brand has its one.

Once you cut them, you must clean up the PCB, removing the old terminals. Note that these capacitors have more common pins, connected together. So, when you replace them with modern types that have only two terminals, you must reconnect the PCB pads together. I use silver plated wire to do that (see the photos). New capacitors are easy to find and are normally much smaller than the original ones, so there are no problems in fitting them. At the end of the soldering work, clean the PCB with a specific product.

Left: bridges to restore traces continuity. Right: the old (blue) and new (black) capacitors.

Repairing the LV board

Repairing the LV board, we have powerful allies: the sockets. What I am suggesting you is the **inglorious way**: just check any transistor with the VOM, without puzzling too much. It seems slow but could be time saving instead. If you prefer the **true man way**, you can remount the transformer and try to debug the circuit in the classic way. Considered the interdependencies that make very difficult the analysis, I prefer the coward approach of checking first every semiconductor. By the way: I have found also faults caused by open resistors, not only by transistors.

Note also that there are two kind of possible problems:

- **the LV board is fault** and is not able to supply the correct voltage. You can only fix it.
- **the LV board is OK**, but the load is excessive. In this case, it's useful to perform the current measurement that we discussed before. Check the voltage across the overload resistors. I have no limit value to give you, but with the above information, it is rather easy to see if a voltage is in the overloaded state. In that case, you have to find out elsewhere the bad guy and not repair the LV.

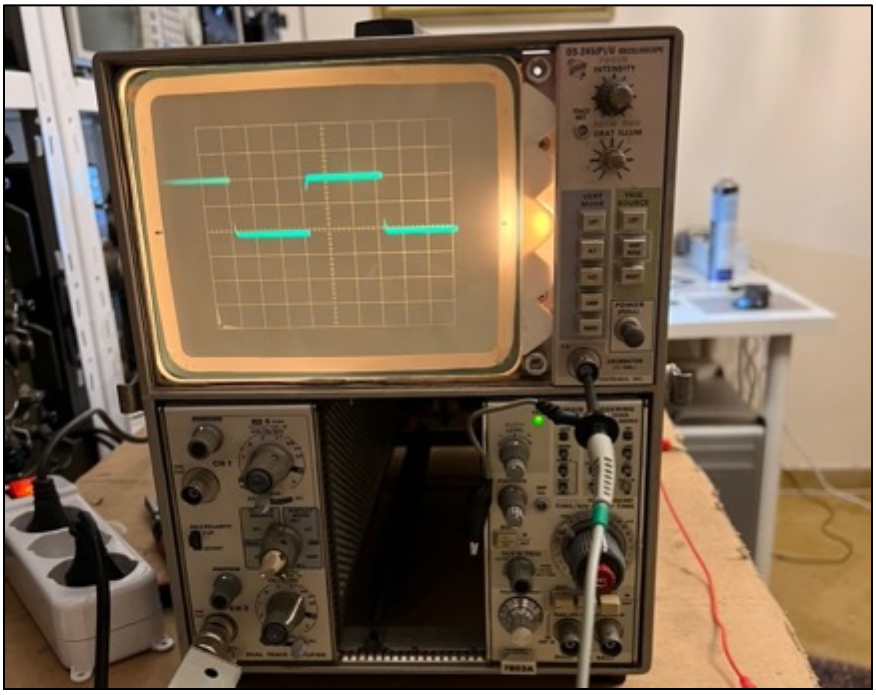
Testing the transistors with the VOM. It is very easy, search on the net, you will find lot of video and tutorials.

Voltages OK

Reconnect other circuits. If the voltages are OK, you can dare to add the circuits that we have disconnected. Reconnect one by one P971, P998, P981 and P962. After each of them, test again all the voltages. If everything is OK, you are ready to reconnect also P1130. I have not a high voltage probe, so I limit myself listening for suspect noises. A temporary light sound of discharges, in my cases, has never been the symptom of problems.

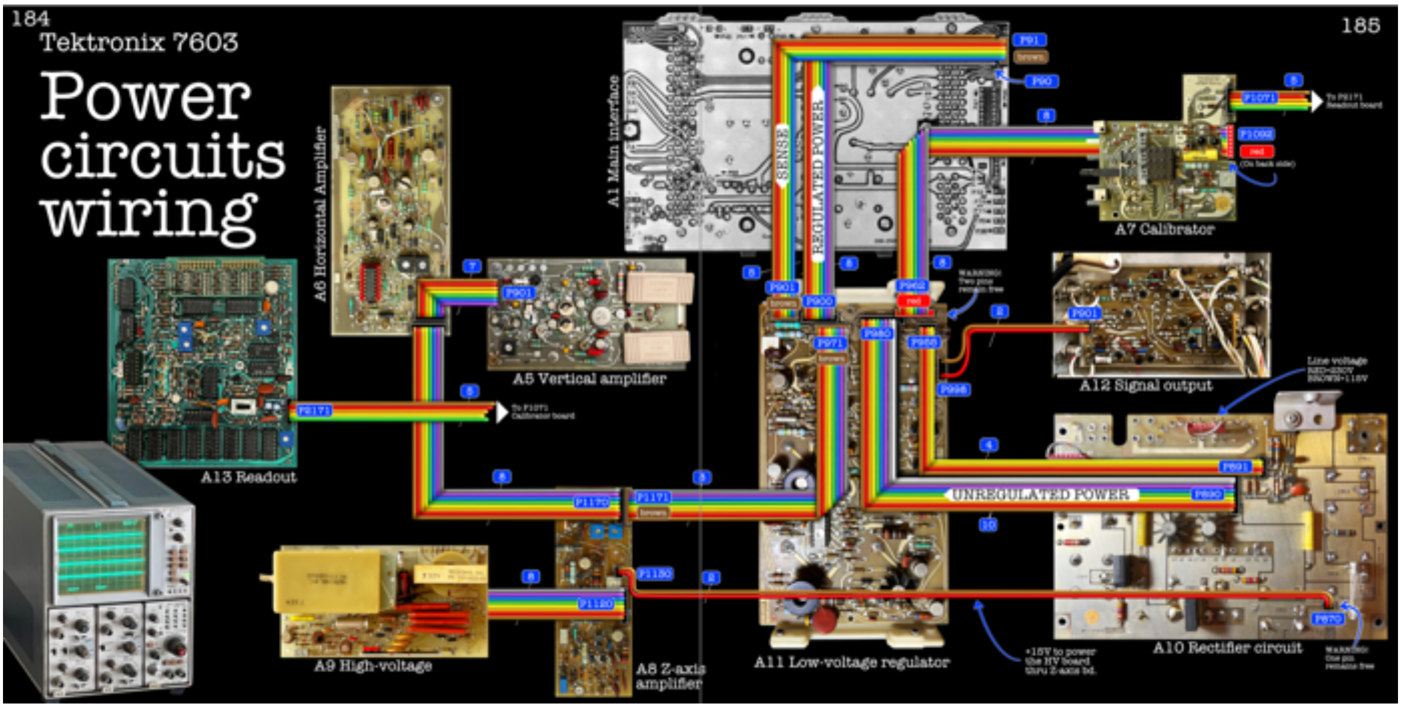
Final tuning: adjust R881 on the LV board to set -50V at its exact value. All the other voltages should stay in their nominal value ±0,1V.

If again no problem arises, no smoke, and voltages remain OK, you can add the plug-ins and test the trace. Don't forget to set the trigger to AUTO, to be sure that the sweep is running.



What a joy when the trace comes back!

Interconnection diagram



The booklet "Surplus parade", that you can download freely in high or low resolution from http://www.k100.biz/parade.htm, contains a drawing with the power interconnections among the boards that compose the Tektronix 7603 oscilloscope.