REPAIRING THE TELEQUIPMENT D52 DUAL BEAM OSCILLOSCOPE & THE SELF CRACKING RESISTORS.

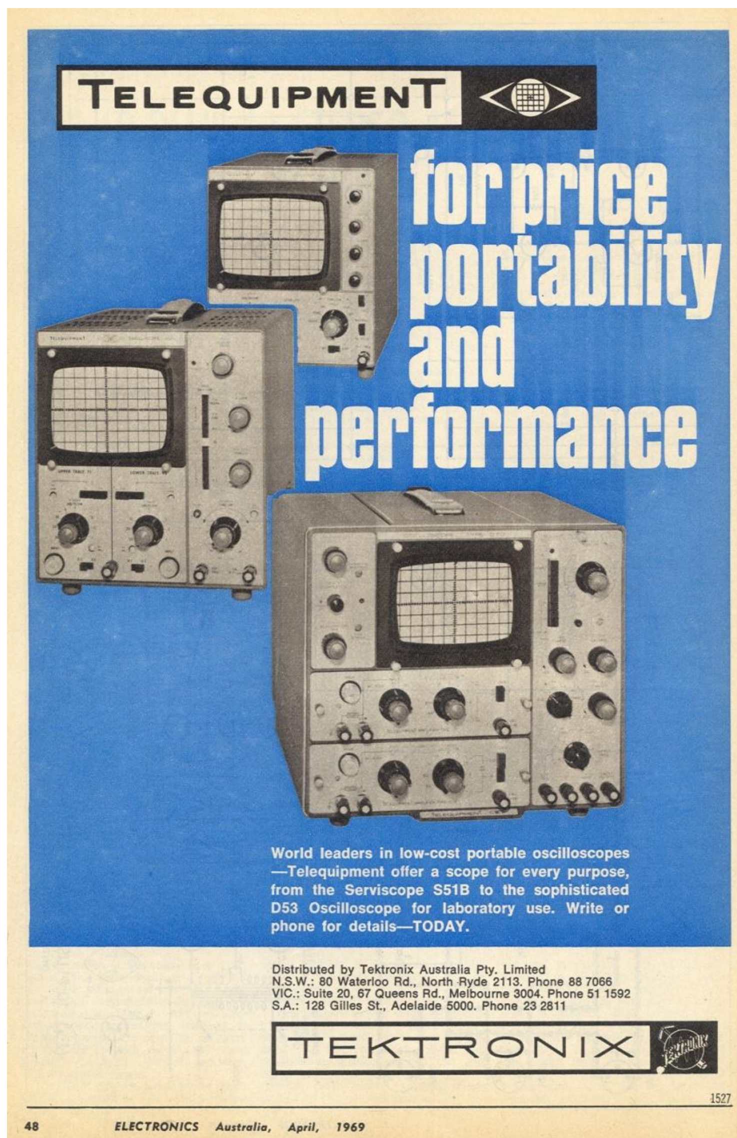
H. Holden March. 2025.

INTRODUCTION:

The D52 Dual Beam 6MHz rated oscilloscope was quite the creation in its day in the late 1960's era.

Being British made, it was a definite competitor with the American made Tektronix scopes. Interestingly, within Australia, both Tektronix and Telequipment Scopes were marketed and sold by Tektronix Australia Pty in NSW (see advertisement below right, from Electronics Australia magazine, April, 1969)

The Telequipment scopes had very characteristic front panels and knobs. Some Telequipment apparatus with these knobs got used as props on the panels of the flying craft in Gerry Anderson's brilliant TV series (with Puppets) The Thunderbirds. As soon as I saw a Telequipment scope, I recognised the appearance as being what I had seen on some control panels in that TV show as a boy. Perhaps that was one thing that made me more interested in Telequipment scopes.

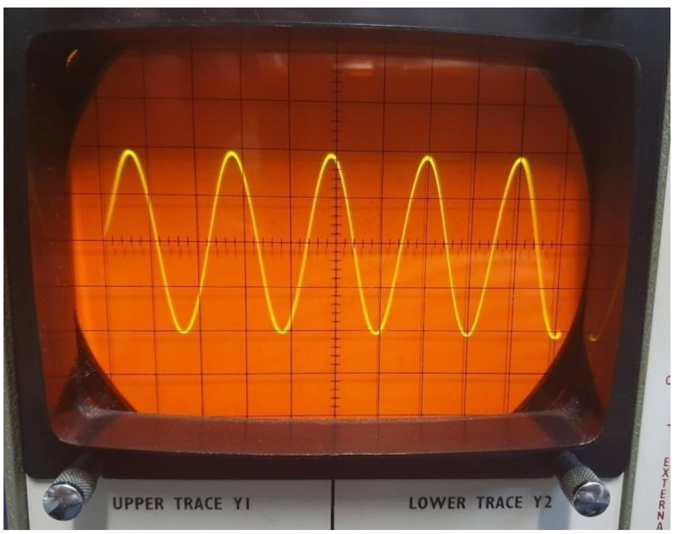


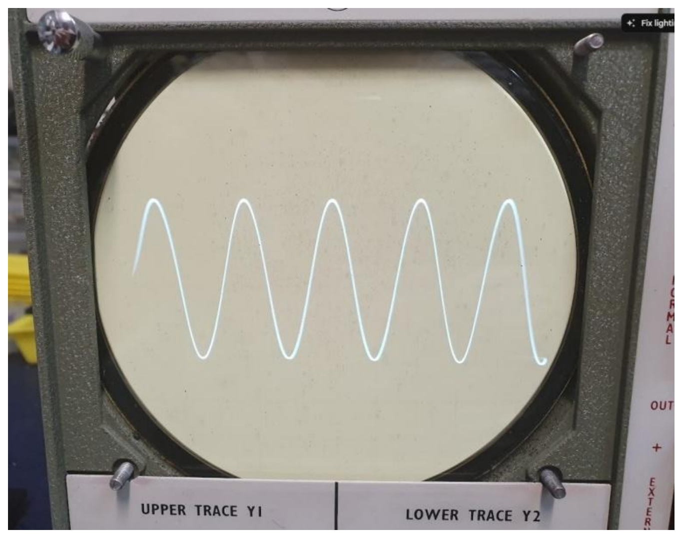
The original arrangement on these units used PL-259 (UHF) input connectors for the scope's probes as can be seen from the advertising photos above. AS can be seen above, I changed these to BNC connectors on my scope to make them compatible with many more modern scope probes. BNC panel connectors that are made to be an insulated panel mount, fit perfectly into the hole for the PL259 connector.

My scope has the Orange filter. This was an option that Telequipment offered when the scope was fitted with a Dual Phosphor CRT. The CRT has a Short Blue and Long Yellow persistence Phosphor. This is designated as P7 (or a GM suffix). If you were interested in short time frame events you would fit a blue plastic filter in front of the CRT (this blocks yellow) or if you were interested in long slower events, such as a cardiac ECG, you fit the Orange filter which lets the yellow through, tints it orange, but blocks out the Blue.

Many D52 scopes simply had the usual Green medium persistence phosphor designated P31(GH) with a green filter. Also a Blue (P11 phosphor) CRT option was available, only in the 12 pin version. There were two CRT variants for this scope, with either 12 or 14 pin bases, therefore, for the D52, there were five possible CRT's it could use according to the manual.

The photos below show the typical result with the Orange filter. With the filter removed the trace looks White, which is the result of blue and yellow together:





The CRT was manufactured in a manner where the Yellow Phosphor was applied to the glass faceplate of the CRT first and the Blue second. Looking at the inside of the CRT (which can be seen through the side wall of the tube) the internal appearance of the phosphor surface there is vivid Blue:

The D52 is a Vaccum Tube based Scope, in that nearly all of the circuitry in the Time-base and Vertical Amplifier circuits uses Tubes. Mainly these tubes are the ECC88 double Triode and the ECF80 Triode-Pentode and the 6AL5/EB91 dual diode.

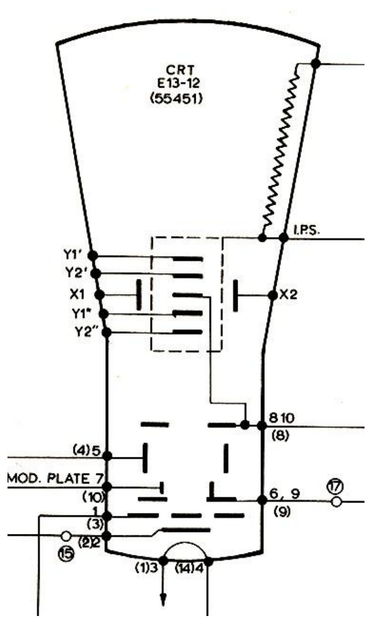
However, this design has an interesting arrangement to support the x10 Gain function. 2N3702 Silicon transistors, two per vertical amplifier channel, are creatively switched into the circuit to achieve it. This is discussed below. Also, the power supply used solid state rectifiers and a single ACY22 germanium transistor was deployed there to support a -12V supply. There are also numerous 1N914 Silicon signal diodes in the circuitry. The CRT's EHT rectifiers were a long stick multi-disc element Selenium type. These Selenium parts gave trouble and required replacement.

THE DUAL BEAM OSCILLOSCOPE:

Most Cathode Ray Tube based Dual Beam Oscilloscopes are actually a single beam cathode ray tube. And the two (or more) beams are created electronically. They have a Channel Switching circuit, which effectively creates a duplicate channel. The switching is either done on Alternate horizontal traces or it is Chopped between traces at a high frequency rate. This function switches between two vertical amplifiers and two beam positioning controls to create the two traces. Therefore, the typical scope, in two channel mode, has an ALT or a CHOP switch to select the method. In other words, all the heavy lifting to make the scope two or more channels, is done by the scope's electronics, not the CRT.

The D52 is different. It has a real twin beam CRT, but one electron gun. The gun is arranged with a beam splitter element which splits one beam into two after it is emitted from the CRT's cathode. There is also an adjustable magnet on the rear of the CRT socket which makes sure that the split beam has equal intensities. The two separate beams go on to pass via different sets of Y deflection plates in the same tube.

Only one set of X deflection plates is required to create the Horizontal trace for both beams. In essence this was a "Cathode Ray Tube Solution" to the problem of how to make a two channel scope. The CRTis quite the masterpiece of Electron Optics, it also sported post deflection acceleration; this allowed the tube to have relatively high sensitivity of the deflection plates, but also a high EHT which favours high beam brightness.



The CRT also has an IPS (Inter-plate shield) electrode to reduce the interactions of the two Y sets of plates. The service manual omitted advice on how to set the IPS voltage. It is usually set to the average deflection plate voltage which is 207V in the D52.

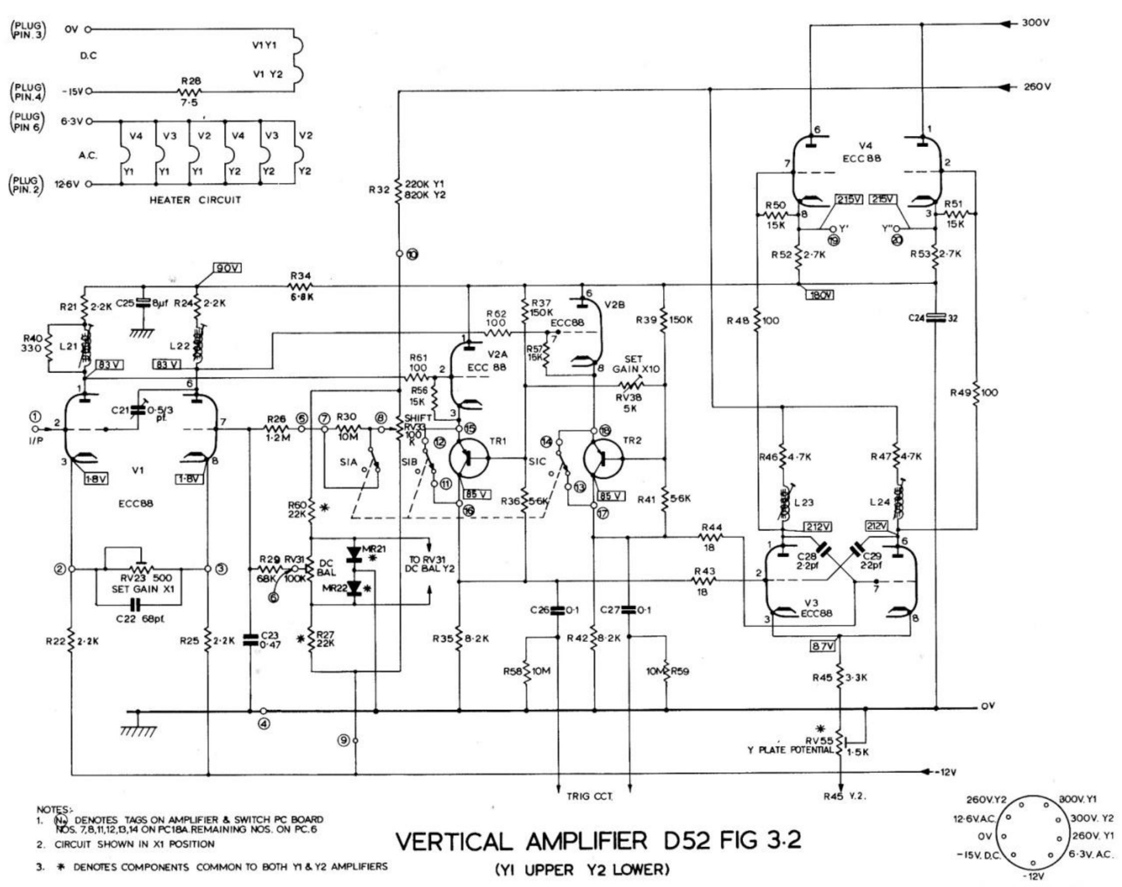
One other interesting feature of the CRT, to achieve retrace blanking, they incorporated an additional control element into the CRT called a Modulation Plate. This is nothing to do with X modulation which is introduced into the CRT's grid in the usual way. It is to fully cut off the beam cleanly for Horizontal retrace. It appears amazingly effective. Again, this is a feature of the particular CRT that eliminated more electronic circuitry. Normally there would be a blanking amplifier for the task.

THE TIME-BASE:

It has speeds of 500,200,100,50,20,10,5,2 &1 mS/cm and those numbers repeated again at uS/cm.

The Horizontal Amplifier's user X gain control expands the trace to 10 screen diameters and the shift control has enough range to allow any part of that expanded traced to be centred on the screen. The Time-base by all accounts I have read was known for easy triggering. I have had no difficulty with it or the Trigger circuits.

THE VERTICAL AMPLIFIERS:



VERTICAL AMPLIFIER D52 FIG 3.2

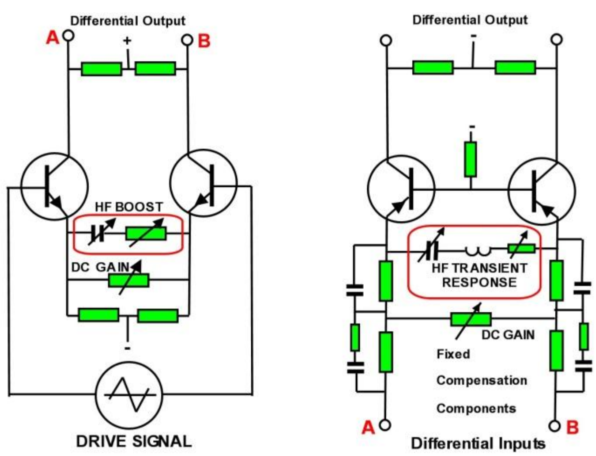
(Y1 UPPER Y2 LOWER)

The Vertical amplifier circuit above shows the arrangement with the original 2N3702 PNP transistors that are used for the x10 Gain boost circuit. When I first got the scope, the transistors in both channels were damaged. At the time I didn't have the exact parts. Ultimately I replaced them with the 2N3906, which is better for the task (explained below).

The cathode currents of the ECC88 cathode follower V2A & V2B drive the transistor's emitters. And since it is a differential amplifier, the transistor's inter-Base resistance RV36 controls the Gain. The output voltage is developed across the 8.2k Collector load resistors. When the x10 gain is not wanted, the transistor's Collector to Emitter terminals are simply shorted out by the switch and the cathode follower behaves as a standard zero voltage gain stage. The circuit above is the same for both channels though some components are shared.

Normally in Oscilloscope amplifier circuitry, in Paraphase or balanced amplifiers depending on how they are driven, at the emitter or bases, determine where the frequency compensation networks go. Generally these are required because the combination of resistance and capacitance in the output circuit (typically from the collectors) rolls off the high frequency response. The arrangements to solve the problem (typically used in Tektronix scopes) are shown below. However the Telequipment D52 scope did not have any frequency compensation networks associated with the Transistors in the x10 gain function, therefore the scope's bandwidth was significantly limited in the x10 gain mode:

COMPENSATING DIFFERENTIAL AMPLIFIERS:



The D52's vertical amplifier performance is very good in the x1 gain mode. The vertical input sensitivity is 0.1V/cm, without the x10 Gain function. With that is is 10mV/cm which is good for a scope of this age. More modern CRT scopes of the 70's and 80's area went to 5mV/cm and later Scopes such as the Tek 2465B went to 2mV/cm maximum sensitivity.

The trigger circuits also sported filters to help the scope lock on to TV Frame or Line Sync Pulses. There is a general assumption out there that if a Scope's Bandwidth is manufacturer rated at X MHz, that it will be 3dB down at that frequency. In at least three scope cases I know of, this is not correct, not even close.

MANUFACTURER'S RATED VERTICAL AMPLIFIER FREQUENCY RESPONSE:

The D52 scope was rated by the manufacturer DC to 6MHz on the 0.1V/cm setting and DC to 1MHz in the x10 Gain or 10mV/cm mode. However they underestimated it, at least from the marketing perspective.

I tested the D52's scope's Vertical Amplifier frequency response using a Tek SG503 levelled sine wave generator terminated into 50 Ohms at the scope's input on the 0.1V/cm (this effectively bypasses the Attenuator) and the result was interesting. Not too surprising because I have seen this sort of thing before.

In the x1 Gain mode, the Vertical Amplifier's frequency response was flat to over 6MHz, and only 3dB down at 7.9MHz. In the x10 mode it was flat to 1MHz and 3dB down at around 1.6MHz , with the original 2N3702 transistors. Better than the manual suggested.

Looking at the x10 gain system, it was obvious why the high frequency response drops off. With the transistors shorted out, the output impedance of the cathode followers of V2A and V2B is low, in the order of a few hundred Ohms. That helps deal with the circuit capacitances which attenuate the HF response. However, with the transistors switched in, in the x10 mode, the collector load resistance becomes 8.2k and this in conjunction with the transistor's output capacitance (about 12pF for the original 2N3702 parts) and the additional capacitance of the wiring and V3's input capacitance, rolls of the HF response to the 1 to 2 MHz region.

I searched around for suitable PNP silicon transistor replacements. The best one I could find was the 2N3906, which has an output capacitance of only 4.5pF. With these transistor's installed the frequency response in the x10 mode substantially improves to a 3dB down point of 3.17MHz. It probably would be possible to improve this further with a frequency compensation network added to improve the HF response in the x10 mode, but I decided that I would leave the scope original, aside perhaps from the better transistors I had installed.

(Other scopes that do better than their Specs suggest: The Tek 2465B is a "400 MHz rated scope" but its vertical amplifiers on levelled sine wave testing with a Tek SG504 Generator and Levelling head are nearly perfectly flat to 600MHz and 3dB down at 650 MHz and 6db down at 750MHz. The more vintage Tek 464 scope, at least the late model one with the upgraded vertical amplifiers, rated as a "100MHz scope by Tek" is flat to 150MHz and only -3dB down in amplitude at 160MHz. It seems that Scope Makers of yesteryear were very conservative with their marketing claims, both for Tek and Telequipment scopes. I'm not sure if a modern manufacturer is as conservative with the Specs of their instruments)

Also, on checking the attenuators in the D52, these are excellent and properly frequency compensated and do not alter the scope's vertical amplifier bandwidth on any setting.

SELF CRACKING RESISTORS:

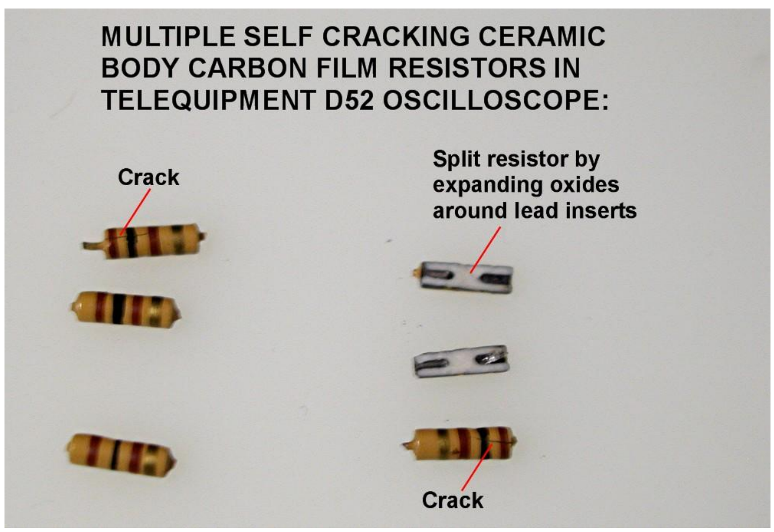
Notice how the Tubes V2 and V4 above both have 100 Ohm resistors in series with their control grids. These are known as "Stopper Resistors" in that in conjunction with the Tube's input capacitance, they form a High cut filter which prevents (stops) very high frequency instability, especially in the VHF and UHF region. These resistors are also used elsewhere in the Time-base section too.

The particular 100 Ohm resistors were all made by the same factory to the same design and it was a disaster waiting to happen. One would imagine the failure rate of a resistor in this application to be extremely low because the resistor current and power dissipation is negligible (near to zero). However the manufacturer had done something that would come to destroy the resistor 50 or more years alter. But they would have had no idea about this at the time, that they had created Frankenstein's Monster.

I pulled the D52 scope out from a period in storage and on powering it there were multiple failures in both the Time-base and vertical amplifier stages. Initially I thought it would have to be a power supply issue, but it was not.

After a number of tests I noticed that some of the Tubes had very low plate and cathode currents. The readings appeared to not make sense. Then I started to discover that a number of the 100 Ohm stopper resistors in series with the tube's control grids had gone completely open circuit. Not high resistance, but totally open. The Tube control grids were floating and accumulating a negative charge and cutting off the tubes.

After removing 6 of these resistors and studying them, there was a horrifying finding. The construction of the resistor was a cylindrical ceramic rod coated in a carbon film. There was a hole in each end in the ceramic rod where there was a metallized coating where the wire leads were soldered in. This is in contrast to the method where metal end caps are used. Corrosion in the holes had expanded in volume and cracked the resistor bodies. One resistor was cracked in totally in half and only barely holding together.



Oxides of metals tend to expand in volume, so if they are encased in a rigid structure the pressure slowly builds up over time. A good analogy of the above problem is seen with Amalgam Dental fillings which develop corrosion on the surfaces mating up with the Dentine. The pressure can build up and crack the cusps off the teeth, though at least the fillings do not work loose very often. Another example is rust crystals expanding under the paint on painted steel surfaces which cause the paint to bubble up from the surface.

Clearly it is superior idea for a ceramic bodied resistor to have pressed on end caps rather than the wire inserts of the type shown above. Though most likely the creator of these resistors at the time had considered that they had produced a "compact and streamlined looking component" and were proud of it and were not aware of what could happen to it 50 years or more later.

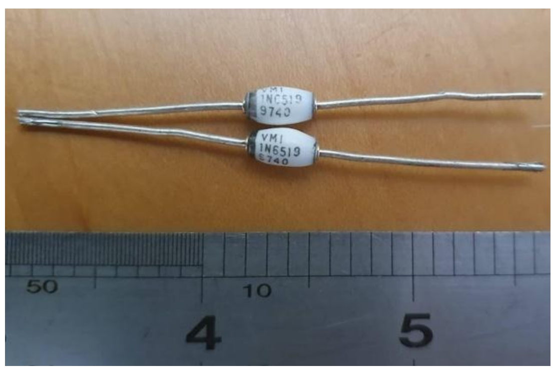
EHT RECTIFIER AND EHT VOLTAGE DOUBLER CAPACITOR FAILURES:

The 2.6kV EHT for the CRT's final anode is derived from a 1060V tap on the main power transformer. It feeds two capacitors & two diodes in a typical twice peak voltage doubler.

The two rectifiers in the EHT circuit were a type of long Selenium stick rectifier in a cardboard tube. These are made up of multiple small discs stacked together in series to create a rectifier with a high reverse breakdown voltage. The method does result in a relative high forward resistance and high range forward voltage drop, but in the application the current for the CRT's final anode is very low. For example the tube's beam current is limited to 500uA.

However, these stick Selenium rectifiers failed and developed significant reverse leakage overloading the 1060V transformer output. I replaced them with some excellent EHT rectifiers made by VMI (Voltage Multipliers Inc) VMI make high quality high voltage rectifiers for many Industrial and Mil spec applications. Occasionally some turn up as spare parts left over from a contract build of Mil spec apparatus and end up on Ebay. They are very special & beautiful parts.

I managed to land a pair of IN6519 rectifiers and had them in my parts box for a rainy day. The original Stick rectifiers were 3.4kV 5mA rated, the 1N6519 rectifiers are 500mA 10kV rated, and they have a relatively fast recovery suited to high frequency supplies too. In this case that feature is not required.



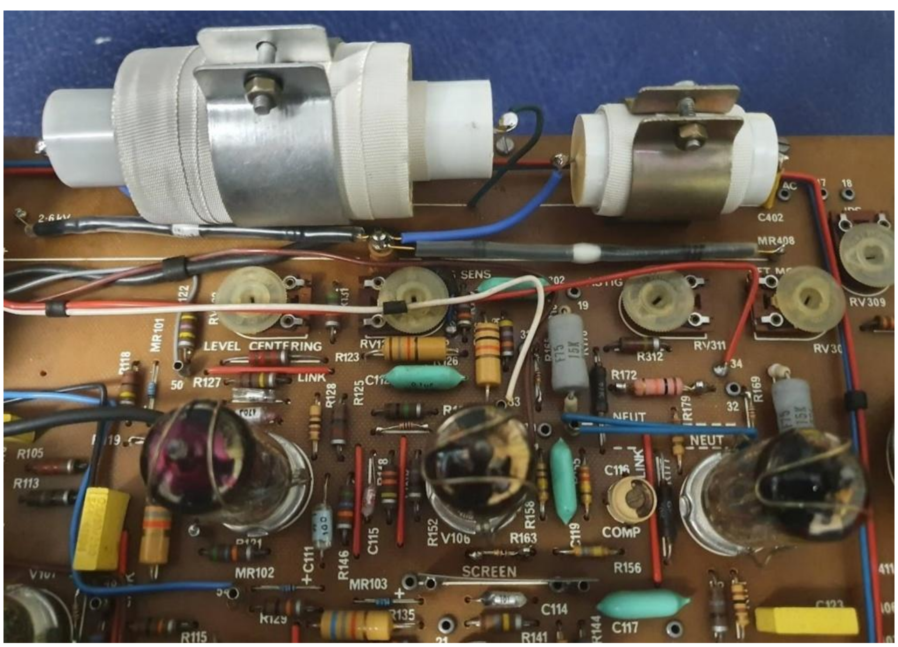
The new EHT rectifiers resulted in an increase in the EHT output from 2.6kV to 2.9kV or about a 11% increase in the final Anode voltage. The total CRT EHT voltage is higher though, because the CRT's cathode circuit is configured to run at -960V.

While the CRT's maximum beam current is limited to 500uA by the circuitry, the individual electrons, being accelerated by by a higher voltage gradient between the cathode and final anode, acquire more energy before they hit the screen phosphor. The beam brightness increased with this change even without a significant increase in cathode current. In some applications where Silicon rectifiers replace Selenium ones, some fit a series resistor, to lower the resulting voltage to near what the selenium rectifier gave before. However in this case for the EHT supply, I decided it was not required and the improved performance was helpful.

Also I discovered that both the capacitors in the EHT voltage doubler section were electrically leaky. Possibly this had provoked the failures of the Selenium Stick rectifiers. The main output filter capacitor appeared to be a large Oil filled type. It is rated at 0.05uF 3.5kV. The other coupling capacitor to the first rectifier was a lot smaller and rated at 0.05uF and 2kV.

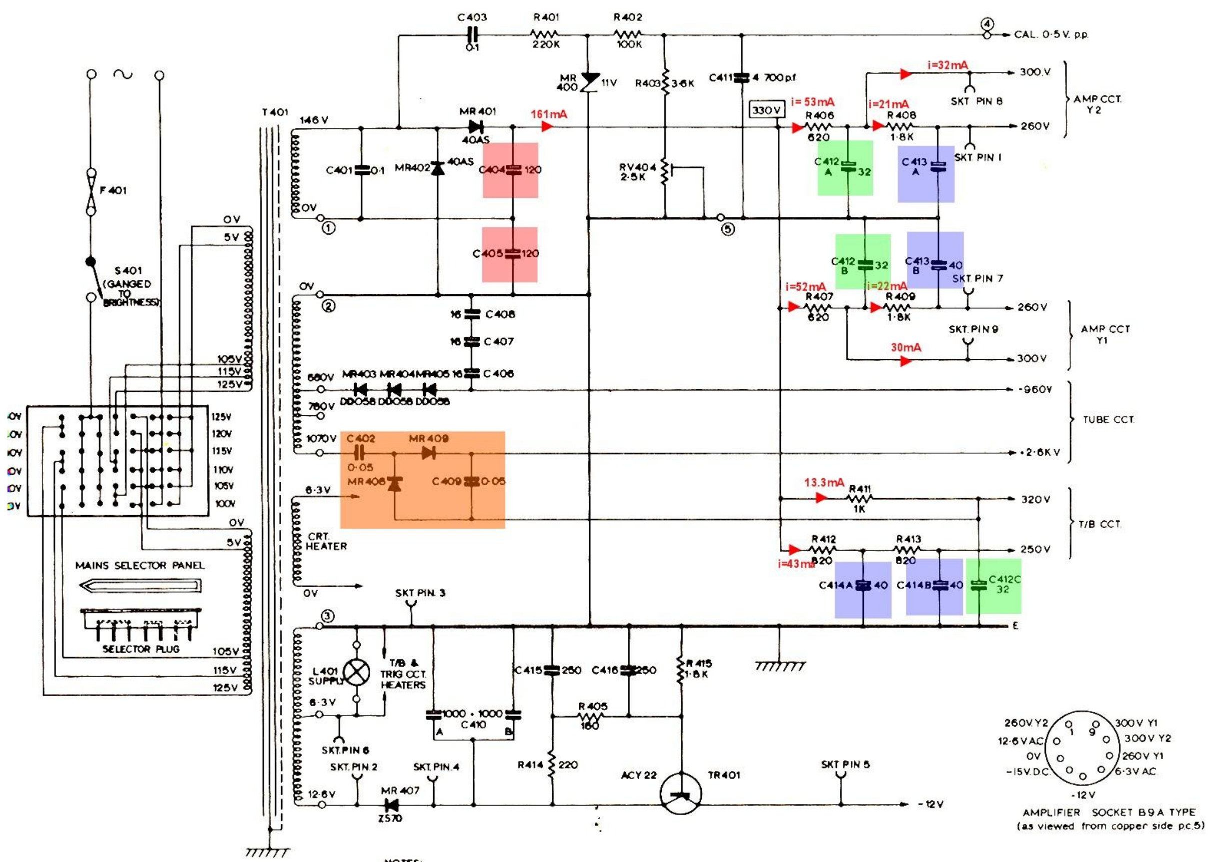
The replacement capacitor I used was created from two 0.1uF 3kV rated caps in series to make 0.05uF 6kV part. (Balancing resistors are not required for film caps of the same value that share charge and each have practically zero leakage). Due to the fact that the capacitors had a smaller diameter than the originals, I built up the diameter by wrapping them in 0.2mm thick fibreglass sheet and finishing them off with Scotch 27 Fibreglass tape. The capacitor at the bottom of the photo below is the original 0.05uF 3.5kV part which was 36mm in diameter and 80mm long. The other smaller capacitor I also rolled up in the thin fibreglass sheet is a 0.1uF 3kV part used to replace the 0.05uF 2kV part. These new parts are shown in the orange box in the schematic below.

The photo below shows the two VMI rectifiers fitted and the two new capacitors in the voltage doubler:

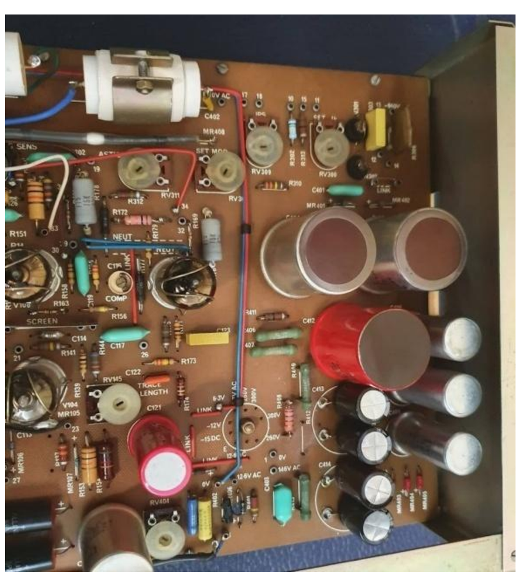


THE ELECTROLYTIC CAPACITORS:

Most of the other Capacitors in the scope were in good order. Aside from some of the power supply Electrolytics which had started to draw excessive current and heat up. The defective ones, shown highlighted in blue below were replaced:



I went to a considerable amount of trouble to decide if C412, a 3 section 32uF 450v capacitor, shown in green above should be replaced. After removing it, extensive testing on its Capacity, Leakage at full rated voltage & ESR were all perfectly normal. So I re-fitted it. Also I could not find anything wrong with the main 120uF voltage doubler capacitors (shown in pink above) so they also got to remain as did most, but not all, of the other electrolytic capacitors in the scope.



SUMMARY:

The Telequipment D52 scope is a very nice Vintage Scope. It does have limitations compared to more modern CRT scopes, in that its Bandwidth is not particularly wide, though better than the 6MHz advertised.

The D52's power supply system is non-regulated (that probably would have given the Engineers at Tektronix bad dreams) and to that extent any Line voltage variations can affect the trace. The internal physical construction is good. One plus is that its unique twin beam CRT does not have any issues associated with CHOP and ALT modes that can sometimes affect more traditional twin beam scopes.

If you find one of these scopes and want to restore it, I would replace the Selenium EHT stick rectifiers and EHT filter capacitors off the bat (if it still has the original parts) because when they fail it stresses the main power transformer.

Likely at least one or two of the Electrolytic caps will require replacing. Also, it pays to check with the meter all of the 100 Ohm grid stopper resistors in case they suffer from the Self Cracking disease. When the cracks start, initially the resistor goes out of spec and high in value, then after a while it suddenly goes completely open circuit. It is probably also worth replacing the original 2N3702 transistors with the 2N3906 as the high frequency performance is better in the x10 gain mode.

The scope is a great workshop asset, especially when fitted with a dual phosphor tube making it particularly good at examining long time frame events.

One application I put it the D52 to recently was to record the output of Sputnik-1's Manipulator circuit which is 2.5Hz, with characteristic steps in the waveform which correspond to the time when neither relay in the manipulator is closed:

https://www.youtube.com/watch?v=k15GSKK_UY0

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