BUSH TV22 RESTORATION. (Dr. H. Holden.)

Update 2020:

BACKGROUND:

The Bush TV22 is an iconic 1950's vintage English Television set. These have a classic Art Deco look and have been used as film props. Often an original set is in very poor condition requiring extensive restoration and electrical alignment.

The photo below shows an example of the iconic TV22:

PHYSICAL RESTORATION OF THE LOPT:

Looking at remarks on the UK's vintage radio/TV forum, the most trouble people have with restoring these sets is the line output transformer or LOPT. The original LOPT was coated in pitch. Apparently, it was not widely known by vintage radio and TV restorers in the UK, that the ideal solvent for pitch was Mineral Turpentine. So many restorers had attempted to remove the pitch, by picking it off, or attempting to melt it off instead, causing damage to the windings, especially the fragile overwind. I had been using a solvent technique for many years to restore pitch coated transformers.

In addition to this, many restorers thought it was a reasonable proposition to power the horizontal output stage when the LOPT still had its original pitch coat with large cracks extending down to the EHT overwind. While driving the moisture out by running a current through the over-wind was helpful, it was still asking for problems and LOPT failure. The moisture simply finds it way back in later.

The photo below shows a typical TV22 LOPT in an untouched set (This photo was provided by Steve Ostler, thank you Steve). This is the way a typical TV22 LOPT looks in the year 2010 + and exactly the way it was in my TV22 before I treated it.

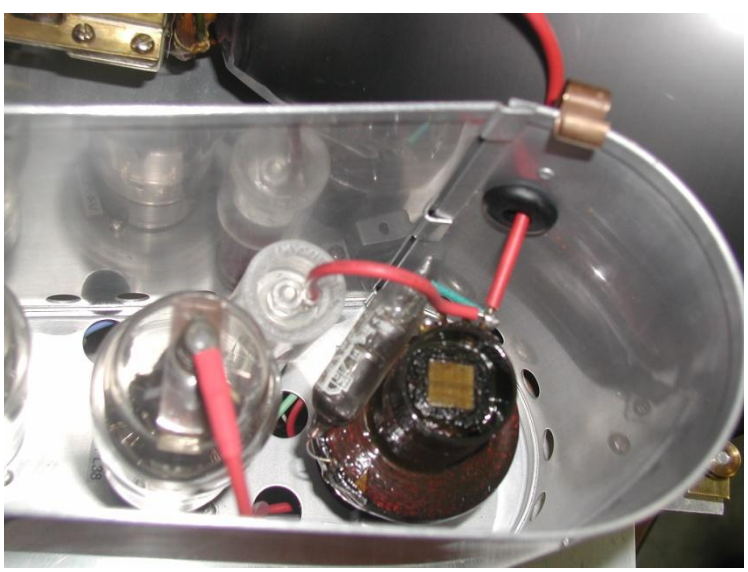
The reason it looks like this is that pitch (tar) contains a range of molecular weigh hydrocarbons. With age, the lower molecular weight ones evaporate. So the material becomes brittle (less fluid) and the volume of it decreases. Therefore cracks appear as the material volume shrinks. These cracks extend down to the surface of the EHT overwind and allow moisture in and compromise the insulation. Still, despite this, many TV22 owners are so enthusiastic to power their sets (often to see if the CRT has emission) that the risk of powering a LOPT in this compromised condition gets ignored.

Unfortunately, pitch of this age and dryness is very resistant to melting again so attempts to heat the pitch, to melt it off, are fraught with hazards and the remaining pitch gets baked on. In addition physically picking at it damages the underlying wiring, especially on the fragile EHT over-wind.

Fortunately the solution is to put the whole transformer in a bath of mineral turpentine (or white spirits in the UK) and the pitch slowly dissolves away in a few days. This also has a joint effect of not having to run any current via the over-wind to heat it, the turpentine solvent drives out and displaces the moisture. I learnt about mineral turpentine dissolving pitch as a teenager, where I used it to dissolve the pitch off the top of tar topped car batteries.

The photo below shows a TV22 LOPT where the pitch was dissolved away with mineral turpentine. After it had dried, the Lopt was dipped multiple times in marine spar varnish (very similar to electrical grade transformer varnish). Another technique that appears to work is to dip the LOPT in Anti-Corona varnish (but I have not tried this myself) but I believe it works.

The photo below shows the LOPT when it has been restored. Of note, early Marconi studio video monitors used multiple coats of varnish to protect and insulate the overwind, they operated at 14kV, so the credit for this idea of using a thick varnish coat, instead of pitch, goes to those designers.



The additional object in the EHT cage is a 0.001uF 15kV rated filter capacitor. This was added because my Bush TV22 has a CRM93 CRT fitted which has no external Aquadag to assist in filtering the EHT voltage.

This capacitor (shown below) also has an acrylic top cover added to prevent corona discharges. It was screwed into an existing hole, where the anode wire for the PL38 previously passed through.

The anode wire for the PL38 was replaced with 25kV capable EHT cable, so that it could pass through another pre-existing hole without a rubber grommet.

These sorts of high quality, high voltage capacitors are available from Surplus Sales, Nebraska.

LOPT VOLTAGE ANALYSIS:

Data Acquisition Tools: **Tektronix 2465B Oscilloscope.**

X100 (Generic x 100 probe) & x 1000 (Tek P6013A probe, 100M Ohm & 3pF).

Tektronix Power Scout Scope (high voltage isolated inputs).

Hitachi V509 Scope (Has H & V sync separators inbuilt).

Fluke 80K-40 1000M Ohm input resistance EHT Probe.

Mains Isolation Transformer.

It struck me as a little odd that the service data I could find on the TV22 did not show oscillographic voltage recordings of the waveforms on the terminals of the LOPT.

Perhaps one reason was that the voltage levels on some of the LOPT connections, exceeds the rating for standard x 10 scope probe. However, in this day and age x100 probes capable of 2kV Peak are easy to get on ebay and not very expensive.

In addition it appears that nobody doing restoration work on the TV22 had ever bothered to document and publish scope recordings of the LOPT voltages. Yet it was clear from the number of people struggling to get the line output stage working in their TV22's and wondering if their LOPT was faulty or not, that it would be a very good idea to have this data acquired from a good working TV22 set.

This article will show that all one needs to know is the wire turn numbers of the LOPT and the B+ boost voltage measured across the B+ boost capacitor along with the duration of the flyback pulse. With this data it possible to work out all the basic voltage waveform shapes & magnitudes and what they should look like at any point in the circuit.

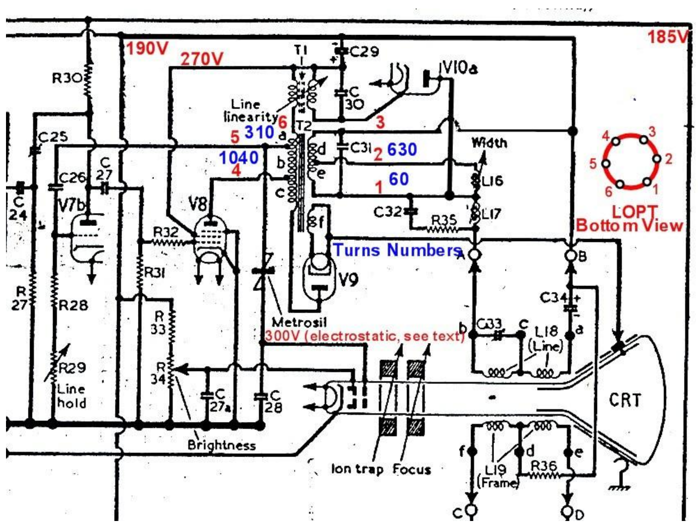
The peak voltages which appear on the Anode of the PL38 and on the Overwind which provides the EHT are easily calculated too. This is possible, because in general, the transformer winding voltages all have an ***average*** value close to zero over the course of one full cycle, as most transformers do which do not run with a significant standing DC current in any winding.(except those in class A Amplifiers & some other exceptions that do not apply here)

Due to this fact, the *flyback peak voltages* are easily calculated on any of the LOPT terminals as they remain in proportion to the *scan time voltages* by a ratio of about 10.4:1 respectively.

Calculated waveforms can be compared with real measurements. This also helps to establish if the documented values of "turns numbers" and "inductances" that have appeared on forums in the past, for the TV22 LOPT, are likely correct…… or not.

LOPT TURNS & INDUCTANCES & RECORDINGS VS CALCULATIONS:

The following is the circuit from the Trader sheet, with the LOPTY pin numbers added and some data on the transformer turns that has appeared in the past from restorers or possibly transformer re-winders:



Source: Ian- G4JQT UK Vintage Radio Forum 2011.

Trader sheet 1091/T38 tag letters	Trader sheet resistance	Bush service sheet tag numbers	Bush sheet resistance	*Measured resistance	*Measured inductance
e	1.3 Ω	1 to 2	- -	1.2 Ω	30 µH
d	14.2 Ω	2 to 3	- -	14.1 Ω	33 mH
- -	- -	1 to 3	15 Ω	15.3 Ω	40 mH
b	30 Ω	4 to 5	- -	29 Ω	89 mH
a	7.5 Ω	5 to 6	- -	7.6 Ω	9.5 mH
- -	- -	4 to 6	36 Ω	36.6 Ω	146 mH
c	800 Ω	4 to 7	700 Ω	880 Ω	1 H
f	1.5 Ω	8 to 9	1.3 Ω	1.2 Ω	19 µH

? 300uH see text

BUSH TV 22 LOPT

Of note, there are no leakage inductance measurements in the table. These are critical measurements too.

The Lopt windings are labelled "a to f" and referred to on this data sheet and most of the oscilloscope recordings in this article refer to those pin numbers too. There is a question about one of the recorded inductance values in the above table, being correct or not:

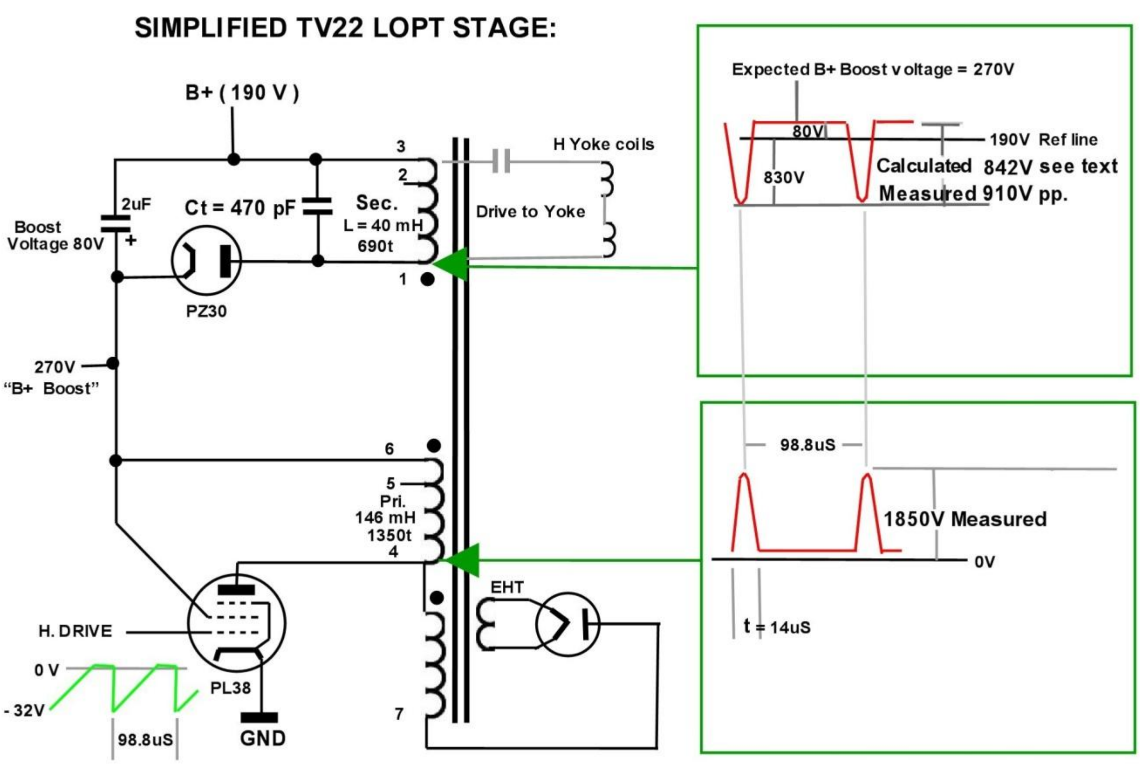
On the topic of the likely winding "e" inductance: 30uH does not appear correct in the table.

The reason is that winding e has 60 turns (if this is correct and other measurements suggest it is) and winding d has 630 turns and is listed at 33mH inductance. Since inductance is proportional to the square of the number of turns, then the likely inductance of winding e is actually:

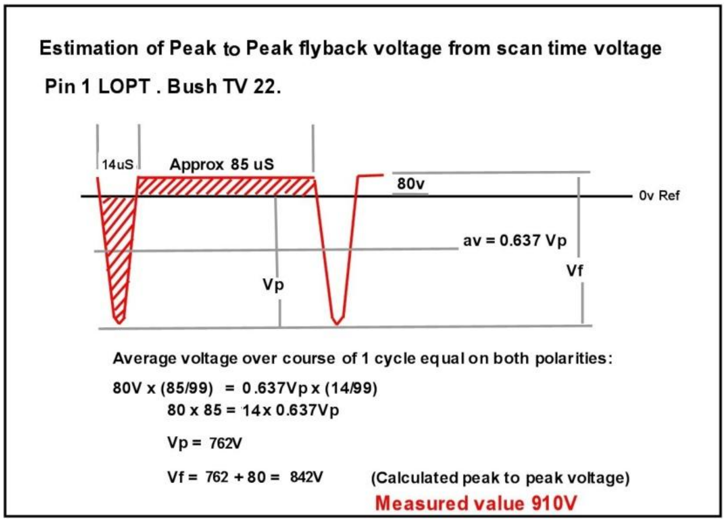
$$(60/630)^2 \text{ x 33mH = 300uH.}$$

A simplified circuit of the LOPT transformer stage is shown below, to help understand the waveforms that one expects to see on each circuit node from the theoretical viewpoint.

The linearity coil is omitted and the width control & Metrosil omitted. Also, the turns data I could find was non specific for the number of turns on the overwind and the EY51's heater winding. It will be shown in this article that these are fairly easy to calculate. But their exact numbers would be better found by unwinding, or looking at an actual transformer. On the other hand, calculating these turns number provides insight into how the transformer works and helps to reduce errors.



The diagram below show how the peak to peak voltage Vf is worked out from the boost voltage. The assumption is that during the scan time the voltage drop across the PZ30 damper diode is very low (30V or less) and it is cut-off during flyback. So, during *scan time* the B+ boost capacitor assumes a voltage close to the value generated between pin 1 & pin 3 of the LOPT, or about 80V. The other assumption is there is no DC voltage of any significance across any of the transformer's windings:



The diagram above shows that when the voltage on the secondary (between pins 1 &3), *during scan time* is 80V, that the calculated flyback voltage pp is about 842V. Measurement gave 910V.

Using the measured value of 910V, assuming the documented primary and secondary turns are correct, this makes the expected pp voltage on the anode f the PL38 (from the turn's ratio) 1350/690 x 910 = 1780 V pp, plus the approx 30V above ground due to the drop of the PL38 when conducting , or 1810v. Measurement of this gives close to 1850V peak above ground/chassis. So, likely the documented turn numbers of the primary 1350 and secondary 690 are correct.

The approximate calculations though appear to underestimate the actual measured peak voltage on the secondary by a factor of 762/830 = 92%. So, in further calculations related to the overwind, it is better to use the measured voltage values seen on the secondary. However, the calculations do help to confirm, that likely the documented turns numbers & inductances for the primary and secondary of the LOPT are correct.

Notice how the ratio of the *measured secondary flyback voltage* is about 910 – 80 = 830V to the measured 80 volt scan time voltage is; 830/80 = 10.4. This fact comes in very useful later helping to determine the likely correct number of turns to power the EY51's heater.

There is another way to cross check to see if the turn numbers quoted for the total primary and secondary might be correct in the table above:

The secondary inductance was measured at 40mH and the primary at 146mH. Since inductance is proportional to the square of the number of turns then $(1350/690)^2$ x 40mH should be close to146mH; it is 162mH, which suggests the documented turns for those windings are probably correct and the measured inductances are correct (or fairly close). For example, if the 1350 turn winding was about 1319 turns, it would fit the calculation exactly, so the calculation is within about a 3% match to the suggested values for turns numbers of the primary & secondary windings & inductances values appear sensible & correct.

One of the more interesting things about the TV22 line output stage is that the width control (inductor) associated with the line coils is a series-shunt system. The load of the yoke remains stable regardless of the width adjustment, so the EHT is not significantly affected by a manual width adjustment. It is probably one of the cleverest width coils seen in vintage TV sets.

It will be shown later, looking at the recording of the Yoke's line scan current, that it appears that the total load of the Yoke & the width control as a whole appears to be in the order of 21mH (the yoke line coils themselves represent 9mH of that measured on my inductance meter). The secondary LOPT inductance of 40mH paralleled with the 21mH has a total value of roughly around 13.7mH #, which requires about 1460pF to tune it to 35.5kHz (which has a half period of 14uS for the flyback). In reality a little less total capacity is required because of a down tuning effect of coupling to the overwind and the overwind being tuned to a similar resonant frequency (see below). In any event, the 470pF tuning capacitor is added (present in the set) across the secondary to get the total capacity high enough tune the arrangement for the correct flyback time of around 14uS.

(# To check this calculation of parallel inductance having the value of about 13.7mH, I measured the inductance of the combined secondary, width coil and yoke, across pin 1 and pin 3 of the LOPT with the inductance meter, with the 2uF yoke coupling capacitor shorted out, it measured 12mH)

EHT VOLTAGE MEASUREMENTS & CALCULATIONS:

The overwind has an inductance, Lo, of 1H tested alone.The inductance (leakage inductance) of the overwind Lio with respect to the LOPT secondary coil, is 0.4H.This is found by shorting the *secondary* out an measuring the apparent overwind inductance with the meter.

From this data the coupling coefficient k of the overwind to the secondary can be calculated:

$$k = \sqrt{\frac{\text{Lo}-\text{Lio}}{\text{Lo}}}$$

Therefore, the coupling coefficient k between the LOPT secondary and the overwind:

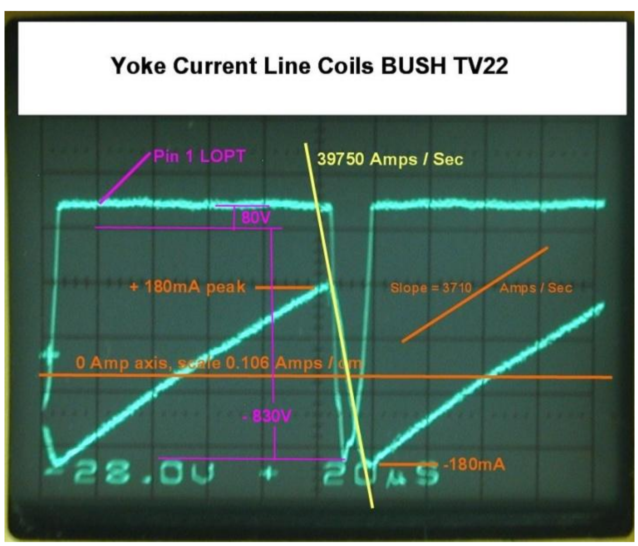
$$k = 0.774$$

The mutual inductance of the overwind and the secondary of the LOPT can now be calculated:

$$k = \frac{\text{M}}{\sqrt{\text{Lo.Ls}}} \qquad \text{Ls} = 40\text{mH} \;,\quad \text{Lo} = 1\text{H} \;,\; k = 0.774$$

Making the Mutual Inductance M = 0.155 Henry.

A recording was made of the yoke current (see below how this was done) which is the LOPT's secondary current. For now the important piece of information is the peak rate of change of current with time, dI/dt, in the H yoke coils of about 39750 amps per second during flyback.This is also the current for the LOPT secondary (ignoring the effect of the shunt winding of the width coil)



On account of the approximate load inductance of 21mH, the H yoke coils and the width control inductor, the flyback voltage on the secondary coil pin 1 of the LOPT is close to 39750 x 21mH = 834V. (830 peak approx by measurement, pin 1 of LOPT).

The peak voltage induced in the overwind terminals, Vop, based on the Mutual inductance between the secondary and the overwind is therefore:

$$Vop = M\, dI/dt = 0.155 \times 39750 = 6161 \text{ volts.}$$

Therefore a peak EHT voltage (not forgetting to add the 1850V from the plate of the PL38 and ignoring any voltage drop in the EY51) based on the above calculation is:

$$6161 + 1850 = 8011V.$$

The measured EHT voltage with a very high input resistance probe (1G Ohm) is 7600V, but as stated in the Trader sheet if it is measured with an electrostatic volt meter it is supposed to be 8kV.

Second way to estimate the EHT:

Do it based on the energy stored in the capacitances at the flyback peak.

The total capacitance of the secondary LOPT winding, the added capacitance (470pF) and the load capacitance of the Yoke & Width Control total, was estimated at roughly 1460pF and the overwind's loading capacitance was estimated at 24.3pF (see below how this was done), then at flyback, *if the core energy was distributed evenly to these capacitances then*:

$$\sqrt{\frac{1460}{24.3}} = 7.75.$$

This ratio is the ratio of the peak voltages that appear across the total capacitances of the overwind coil to the total capacitances of the LOPT secondary coil & its 470pF tuning capacitor & yoke & width coil capacitances.

This root is because the energy stored in a capacitor is proportional to the square of its terminal voltage. If the peak voltage on the secondary terminals is 830V, then using this analysis the peak voltage on the overwind terminals should be about 7.75 x 830 = 6432V making the expected EHT:

$$6432 + 1850 = 8282V.$$

Therefore the two methods roughly agree that the expected EHT should be about 8kV.

Overwind turns estimate:

While it was easy to estimate the EHT the overwind would produce, because the overwind's inductance and leakage inductance was known and therefore the mutual inductance could be calculated and the winding capacitances estimated as a second check on the calculation, it poses the interesting and more difficult question of how many actual turns might be on the overwind to:

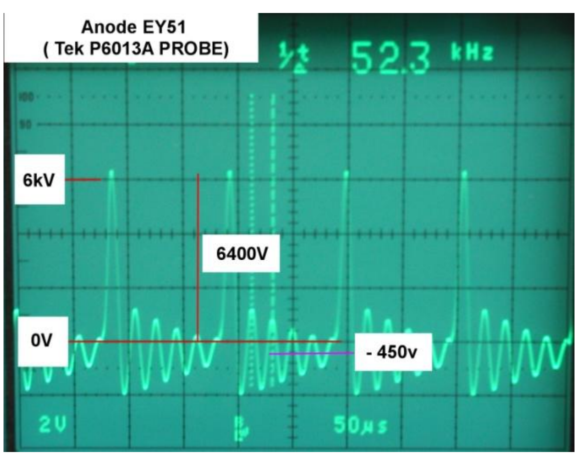
1) Achieve its measured inductance of one Henry.

2) And generate the approximate 8000-1850 = 6160V.

It is not just a matter of the turns ratios of the secondary and its peak voltage at flyback time to calculate the LOPTY overwind turns, because of the less than tight coupling (k= 0.774) between the secondary. In addition the approximately ½ inch square iron occupies a large % of the cross sectional area of the primary and secondary windings, but less so for the overwind, which has an internal diameter of about one inch and a fair proportion of the cross sectional area is effectively space.

The peak voltages during flyback represent a mode where voltages are induced in all the LOPT's coils without significant power transfer from one coil to the other. On the other hand, during scan time, the LOPT is operating in transformer mode.

Therefore, to establish the basic transformation ratio of voltages between the windings, it is probably better to look at the measured voltages during scan time where the LOPT is operating in "transformer mode" . This would mean the measurement of the overwind voltage and the loading by the probe for that measurement had much less effect on it, especially since the voltage is much lower and the current drawn by the probe much less than on the very high peak voltage that produces the EHT.



Ignoring the oscillations during scan time caused by the leakage inductance of the overwind (see below) the average voltage seen in the recording above is close to - 450V. Notice the EHT is loaded down to 6400v by the 100M ohm resistance of the Tek P6013A probe, versus the 1000M Fluke probe that measured the EHT at 7600V on the EY51 cathode.

Therefore the voltage ratio of the overwind to the secondary, during scan time is 450/80 = 5.625.

This suggests the overwind turns are very approximately 5.625 x 690 = 3881 turns.

To check if this suggested value of 3881 turns makes sense for the overwind:

Looking at the relative measured inductances of 1H and 40mH of the LOPT's unloaded windings, the turn's ratios should be very roughly about:

$$\text{Turns ratio} = \sqrt{\frac{1}{0.04}} = 5$$

Therefore with the 690 turn secondary, the overwind turns would be about 690 x 5 = 3450 turns.

This possibly underestimates the turn numbers as due to the physical geometry of the overwind and its spacing from the iron core, it probably requires more turns for a given inductance than the secondary wound closer to the core in a long solenoid like configuration rather than a pancake like configuration.

So currently my best estimate is approximately 3400 to 4000 turns for the overwind.

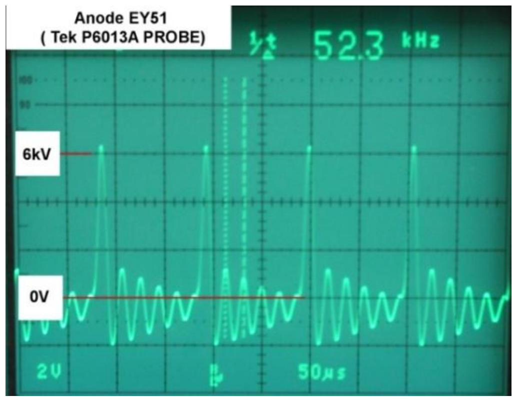
However, a TV22 LOPT had been layer rewound with 2960 turns of 0.11 mm wire and it was reported on a forum that this worked, but the resultant EHT was not documented. Therefore the turn numbers on the original LOPT could be in the order of 3000.

One difficulty is exactly counting the real number of turns from a defunct overwind, with the very fine easy to break wire and it would be very easy to lose count, unless a counter setup was used with a winding-unwinding machine. Ideally a replacement overwind would be wave wound to keep the self capacitance low and similar to the original design.

One interesting thing that this analysis has shown: You do not have to know the exact number of turns on the overwind to successfully rewind it. If the overwind is made to be a similar geometry to the original, it can be wave wound as a slightly taller coil, then turns can simply be removed from it until it has the correct inductance of 1H. And its leakage inductances then can be easily checked to with respect to a shorted primary (0.34H) or a shorted secondary (0.4H) then it is guaranteed to produce the correct EHT voltage.

OVERWIND SELF CAPACITANCE AND RESONANT FREQUENCY:

This frequency of the LOPT's tuned secondary (loaded with the yoke & width coil) is about 35.5 kHz, while the overwind "apparent resonant frequency" is higher around 52kHz. The voltage on the Anode of the EY51, with respect to the chassis, was recorded, the vertical scale is 2kV / cm:



The measured peak is around 6.4kV being lower under test with the 3pF and 100M loading from the Tek probe, compared to the Fluke 1000M probe which gave 7.6kV at the cathode of the EY51 rectifier.

It might be tempting to think that the resonance seen in the overwind, after flyback (during scan time), could be calculated from the overwind's inductance (1H) and the Overwind + the EY51's rectifier's Anode capacitance. In fact, it cannot be calculated from that data.

The overwind's oscillation seen during scan time are due to its self capacitance tuning its ***leakage inductance***, not its main inductance:

The reason is that when the overwind is resonating, in an unloaded state, during scan time, a large proportion of the overwind's inductance is neutralised. This is because of conduction of the damper diode and then the PL38, during the scan time forces a fixed DC voltage across the LOPT primary.

In a transformer, if a winding is either shorted out (or has a fixed DC voltage applied) then via mutual coupling, this eliminates the inductance in other windings on the core, or at least that mutual part which is *linked* with the windings (magnetically). So the inductance that is evident on a secondary winding, with a fixed voltage applied to the primary, represents leakage inductance.

Therefore, to calculate the likely total overwind capacitance requires that the leakage inductance of the overwind, with respect to the transformer ***primary*** be measured. So with the primary shorted out (pins 4 & 6) the overwind leakage inductance was measured at 0.34H on my inductance meter.

Therefore the 52.3kHz seen on the overwind output (anode of the EY51) *during scan time* represents the self capacitance of the overwind + the anode capacity of the EY51 + the capacitance of the Tek probe tuning the leakage inductance.

Solving for the total capacitance yields close to 27.3pF, so subtracting the 3pF from the Tek probe which made the measurement, the overwind self capacitance, or total capacitive loading on it will be close to 24.3 pF.

Going back to the conditions *during flyback*, when the field in the core of the LOPT is collapsing, the resonant frequency of the 690 turn tuned secondary & yoke & width coil assembly tuned with the 470pF capacitor, the frequency is around 35.5kHz.

Combining the overwind's measured inductance (1H) with the 24pF estimated self capacitance, yields 32.5 kHz.

Therefore it appears that the overwind main inductance (in the unloaded state during flyback and excluding EY51 conduction on peaks) has been self tuned to approximately the same resonant frequency as the secondary circuit of the LOPT.

But it should be remembered, ***during scan time***, the resonant frequency seen on the overwind's output terminal is dependent on leakage inductance, not its main inductance value. Therefore the resonant frequency of the overwind coil, as seen in the recording, is higher at 52.3 kHz, not representative of the resonant frequency during flyback.

EY51 HEATER WINDING:

A rough estimate could be made of the expected number of turns required. These are easily counted on the surface of the former though.

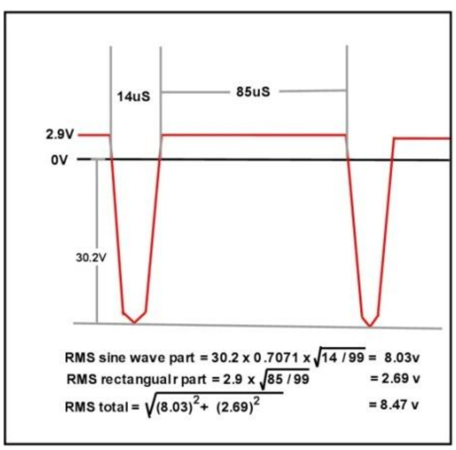
It is a little more complicated than it looks to calculate. The heater wire in the EY51, does not care about which direction the current is flowing, it is the heating or "rms effect" that is important. So, in this case, to estimate the required number of turns to power the EY51's heater to the equivalent of 6.3V DC, requires the analysis of a complex wave shape as shown below.

Other useful data is that the EY51 heater is 6.3V and draws 90mA at that voltage and an effective resistance of 70 Ohms at its operating temperature and has a power of 0.567 Watts. It is a matter of calculating the rms value of the waveform during scan time and adding that (with rms addition) to the rms value of the wave during flyback. Looking at the single layer winding on the surface The LOPT in my set has what appears to be around 25 turns powering the EY51, without an exact count.

However these turns are very near one end of the laminated iron core and in that location not all the lines of the main flux link the winding. As a rough estimate I would "guess" that a calculation to predict the number of turns would have to target an rms voltage of at least 30% higher than the required 6.3V for the EY51 heater, or about 8.2V rms (off load), which would help to allow for the loading on the winding and the imperfect coupling, so that in the loaded condition the EY51's heater received its 90mA current.

We know that the ratio of the scan voltage time to the peak voltage is 10.4. We also know that the scan voltage during the scan time on the secondary is 80V and the turn numbers are 690.

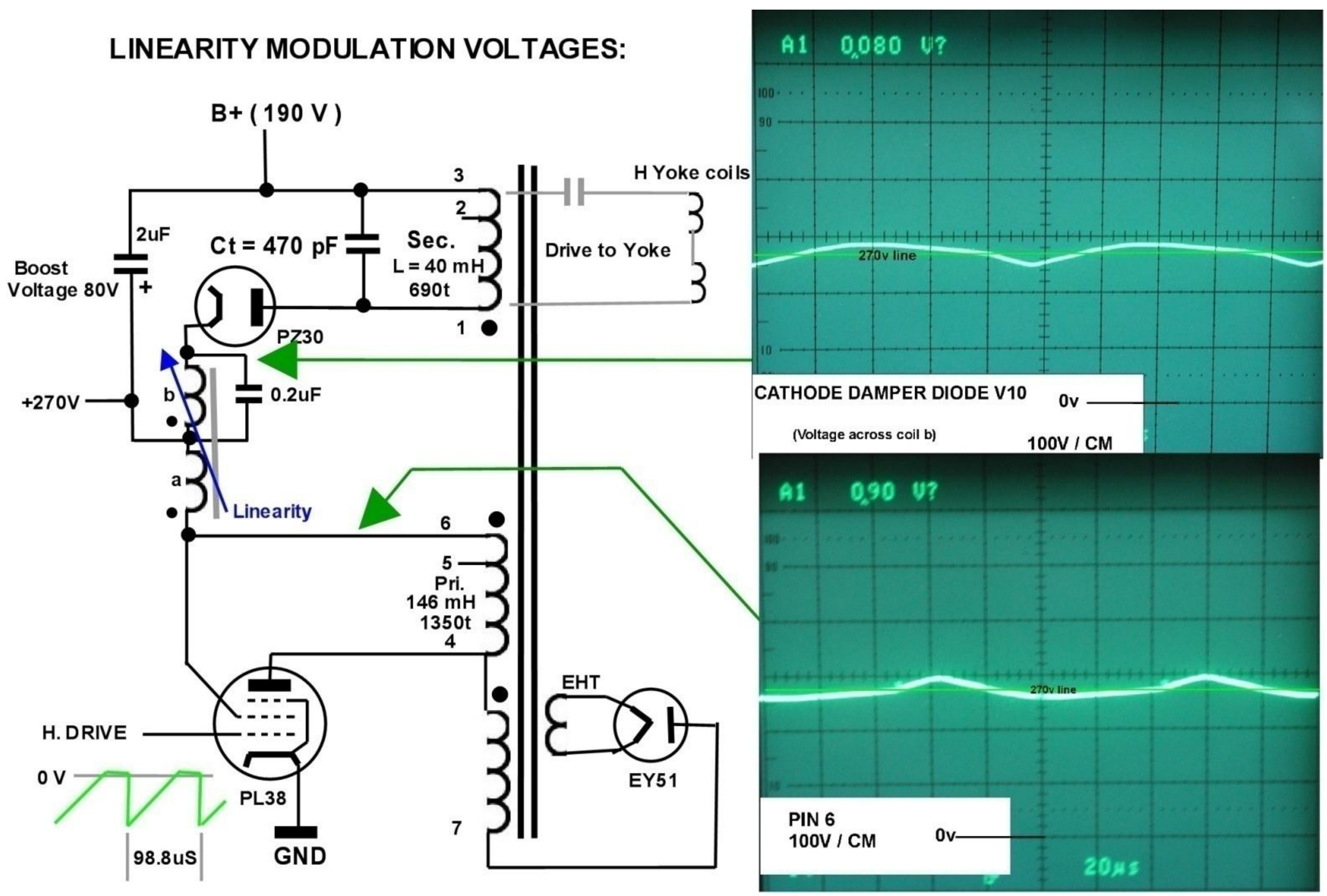
Therefore with 25 turns as an example, the scan time voltage in a 25turn winding is (25/690) x 80 = 2.9v. And therefore the peak voltage, during flyback is 2.9 x 10.4 = 30.2V. The calculations below show the rms voltage generated by 25 un-loaded turns. This transpires to be about 8.47V, which agrees with the very rough estimate of around 8.2V in the unloaded state that the winding should likely produce:



Once again, the calculations help confirm what might be expected. However unwinding (or just counting) this winding would give exact turns numbers.

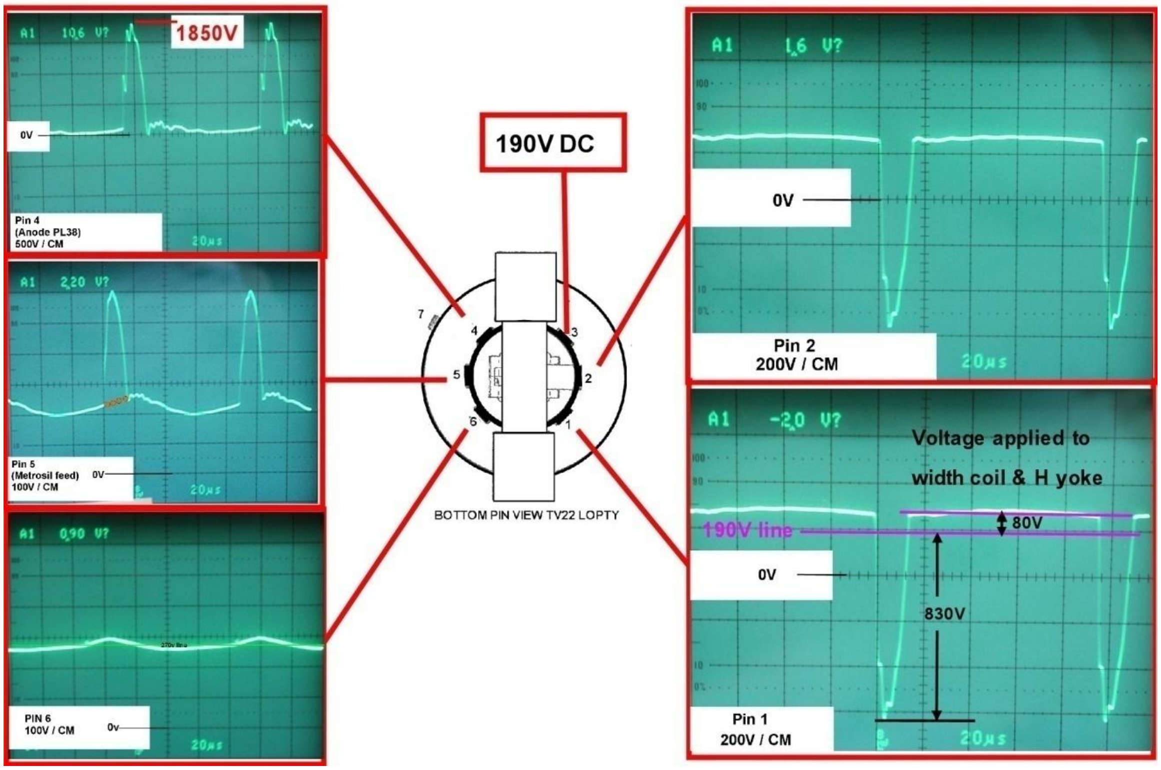
LINEARITY CONTROL:

Putting the linearity control back into the circuit; oscilloscope recordings show that the job of this control is to modulate the supply voltage to the primary of the transformer. It is interesting, because the control is split in two as a means of phase reversing the modulation voltage generated across coil B with the 0.2uF tuning cap there. The modulation voltage is essentially parabolic falling toward the centre of the scan and rasing again toward the end of the scan:



RECORDINGS, LOPT PINS:

I have made the following recordings. The pin numbers, of the lopt, viewed from below, pins 1 to 6 are in a non customary anti-clockwise direction:



The recording on pin 5, shows the voltage presented to the Metrosil is similar to the linearity correction voltage added to the boost voltage but with a flyback pulse superimposed or riding on it, above the level of the orange dots added to the recording.

THE METROSIL:

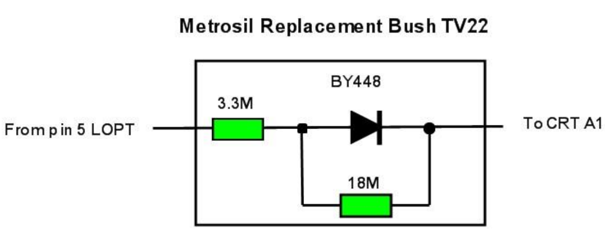
As noted the voltage feed to the Metrosil is a combined flyback pulse, riding on the linearity modulation voltage (orange dots added to the scope recording).

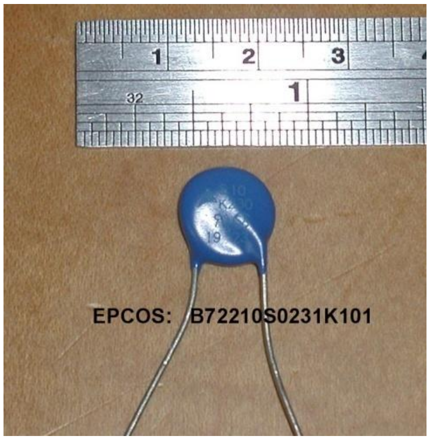
A measurement with the original Metrosil, and using a 100Meg ohm input resistance probe shows that the initial voltage in the moment before the 0.1uF filter capacitor gets discharged by the 100M probe, is about 350V. The load of a 100M (from a high voltage probe) quickly causes the voltage to drop to 300V due to the high effective resistance of the Metrosil under those operating conditions.

The Metrosil is a vintage Silicon Carbide VDR. It partially rectifies the pulses and adds a value to the average voltage. For example, if the Metrosil is replaced by a simple resistor, the voltage obtained represents the average of the waveform on pin 5 of the LOPT which is only around 255 volts. The Metrosil enables a 300V supply. However, since its internal resistance under the operating conditions is very high, it is very important that in all TV22's, the 0.1uF filter capacitor in the CRT's A1 connection is renewed and is in perfect condition with zero leakage.

In the past some TV22 owners have replaced the Metrosil with a diode and a resistive divider. This requires a connection to ground. Experiments indicated it was possible to replace the Metrosil with another "Two Terminal Device" composed of a diode and two resistors, this configuration produces 300V which drops down by -30V with a 100Meg Ohm load, less than the 50V drop with the Metrosil and a 100M load, so it results in a slightly "stiffer" 300V supply, though this aspect is somewhat academic, as the CRT's A1 current is very low.

Two replacement options:





I tried a number of modern MOV's (Metal oxide varistors) in the application. There is a voltage range where it can be too high or too low (off load) then under an additional load a different voltage. The closest one I could find as a replacement was the MOV by EPCOS part: B72210S0231K101.

As noted, the original Metrosil, in my set at least, off load results in close to 350V and when the 100M probe resistance discharges the 0.1uF capacitor a little, and creates a voltage divider with the metrosil, the voltage drops to 300V. With the EPCOS B72210S0231K101, the initial voltage is also 350V and with the load of the probe drops to around 290V.

Going to lower voltage MOV's such as the B72210S0171K101 or B72210S0151K101 results in a stiffer voltage source with the 100M load of the probe, but the initial off load voltages are too high approaching 400V. Though, if these lower value MOV's were used, it could look ok on testing with a meter, due to the load of the meter and fool somebody that it was ok, but in the working or off load condition the CRT's A1 voltage would be a little high.

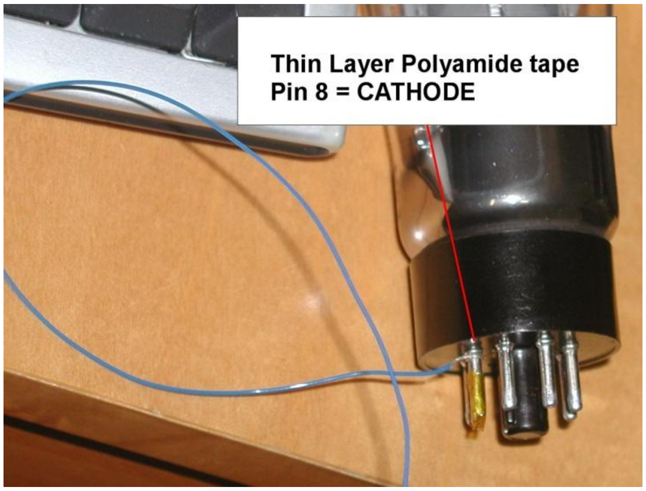
GRID DRIVE VOLTAGE PL38:

The recording of this is shown below, it is around -32V pp:

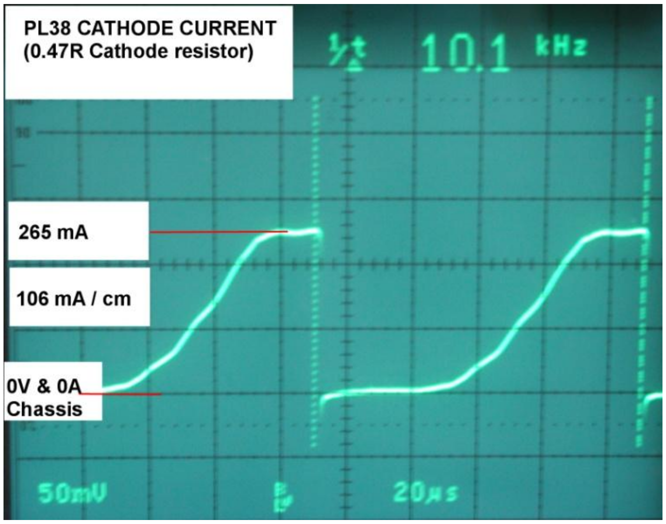
The PL38 is driven into grid current over about the final 20uS of the line scan. The average PL38 anode voltage is fairly low during the entire scan, in the region of 30 to 50V.

CATHODE CURRENT PL38:

It is awkward to disconnect the cathode connection (pin 8) of the PL38's socket under the chassis, so the method below was used to isolate the cathode for a test. The voltage developed across a 0.47R resistor added is low, so it does not matter that the insulation is thin:



The recording shows the cathode current and as can be seen it levels over the last 20uS or so of the H scan where the PL38 is drawing g1 grid current and is in a saturated state:

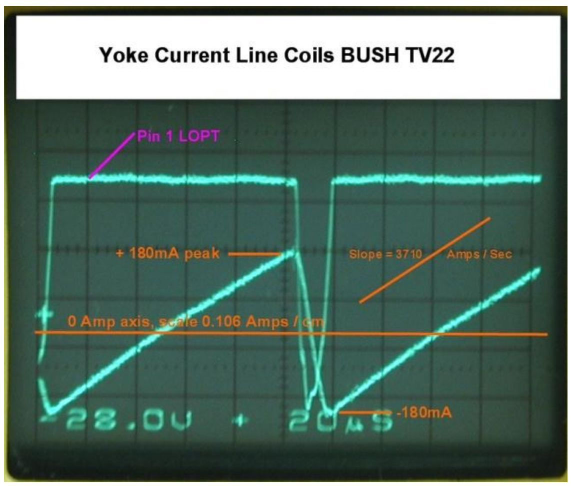


LINE (HORIZONTAL COILS) YOKE CURRENT:

The ultimate job of the line output stage (apart from generating EHT and other auxiliary voltages for the CRT) is to provide a sawtooth current to the line deflector coils.

The following recording was taken. This sort of recording was made possible by using a special oscilloscope, the Tek Power Scout. This scope has totally isolated inputs. It has total isolation between the two probes of each channel and isolation of the Earths of those probes too. Each probe/probe common can be connected across any circuit component irrespective of its relationship to ground (within some high voltage limits).

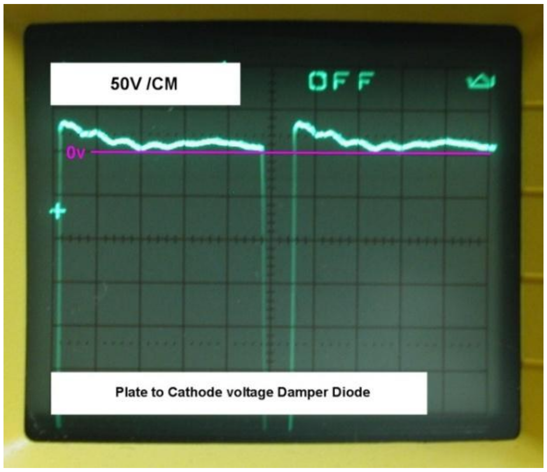
To measure the yoke current a 0.47 Ohm current sensing resistor was placed in series with the Line Yoke coils and one scope channel monitored the voltage across this. And the other channel connected to pin 1 of the LOPT (the yoke's secondary voltage). It elegantly proves the point that a rectangular voltage applied to a predominantly inductive circuit produces a linear current ramp (for a while initially at least):



The voltage applied to the Yoke & width control by the secondary of the LOPT, during scan time, is a rectangular wave of approximately 80V in amplitude (See recording pin 1 with respect to the 190V reference line), the rate of rise of current in the yoke & width control assembly, from the recording above is 3710 Amps / second.

This is suggests the width control & yoke together presents a rough inductance of 80/3710 (because the rate of rise of current with time = V/L initially at least for an inductor connected across a DC supply). So the total load inductance is in the order of 21mH. The yoke on its own though measures about 9mH, so the rest is contributed by the width control. As noted before, the net parallel inductance of the width coil & yoke with the LOPT secondary comes to about 13.7mH on calculation and about 12mH on testing (with the 2uF coupling capacitor shorted out).

PZ30 VOLTAGE A-K RECORDING:



In this case the Tek power scout scope probe was connected across the anode and cathode of the PZ30 damper diode. Since the PZ30 is responsible for the left had side of the scan, the current through it is higher immediately after flyback, and the voltage across the A-K is higher at that time, it peaks to about 35V immediately after flyback and decays toward the middle of the scan.

OTHER LOPT RESONANCES:

There are some high frequency oscillations, riding on the flyback voltage, most easily seen on the Anode waveform of the PL38 than on any other test point. The question might be asked where do they come from ? These represent the primary inductance resonating with the primary self capacitance. They tend to extend to the whole time that the PL38 is not conducting (see recording pin 4 LOPT), so they occur from the start of flyback to about 1/3 the way into the line scan. These oscillations damp off when the PL38 starts to come back into conduction. These minor oscillations are superimposed on the flyback waveform during flyback and are seen to a lesser extent seen on the secondary winding flyback voltage.

Lopt summary:

With the data presented above, it should be readily obvious testing a LOPT if it is defective or good. The oscilloscope recordings provide a useful reference. In addition the information may help restoring or re-winding a defective or damaged LOPT when that is required. Obviously if the LOPT has shorted or open turns it will require re-winding.

The TV 22 LOPT has also malfunctioned because of the cracked pitch, allowing the overwind to absorb moisture. Driving this out by heating it is only a temporary fix. However if the pitch is removed with the chemical method outlined above, then the moisture is also displaced and the coat of varnish protects the overwind surfaces from corona discharges and that problem is solved.

IMPROVING THE TV22's INTERLACE:

The TV22 has been reported as having poor interlace.

Good Interlace is dependent on the vertical oscillator being triggered by the separated vertical sync pulse and the exact ½ line difference between consecutive vertical sync pulses, from one field to the next, being perfectly preserved. If the vertical sync pulse is separated out well from the composite sync pulses and applied to the vertical scan oscillator at a suitable level and there are no other interfering signals, then good interlace is usually assured.

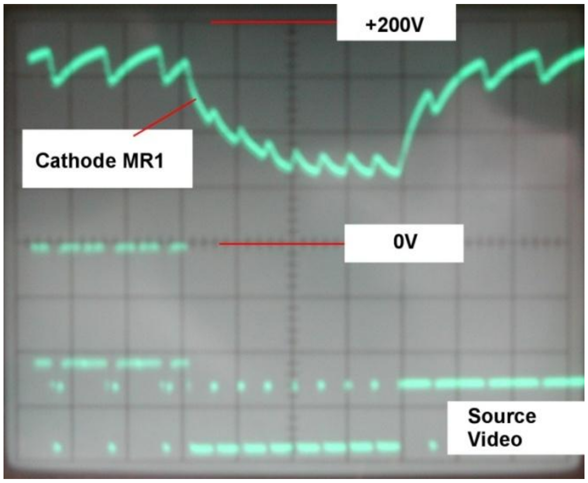
The leading cause for poor interlace is when the vertical oscillator finds itself being triggered by horizontal pulses, rather than the timing provided by the separated and filtered vertical sync pulses. In this case the half line delay is lost and one field simply scans directly over the next and accurate interlace is lost. Or there can be grades of this trouble which results in varying degrees of observed line pairing in the scanning raster.

One of the main causes is poor filtering of the HT rails, flooded with line rate pulses (from the line scanning stages) due to aged filter & bypass capacitors. This is aggravated if the level of the filtered vertical sync pulse, presented to the vertical oscillator is low. So increasing the V pulse injection voltage to the V oscillator may help here by lowering the value of the 100k resistor. But this is not really the ideal solution.

Vertical Sync separators and vertical pulse filters for correct interlace must have two different designs depending if equalization pulses are present or not:

In systems where equalization pulses are present, the vertical sync separator can simply be an R-C filter. The equalisation pulses prior to the vertical sync pulse leading edge ensure that just prior to that edge the capacitors in the filter have exactly the same voltage on odd & even fields. However in systems like the 405 line UK system, no interlace pulses are present. This is why "interlace diodes" were used, to help ignore the average level of the H sync pulses prior to the vertical sync and only respond (pass charge) to the vertical integrator filter capacitors on the leading edge of the vertical sync. This would also imply that integration of the composite sync, to any great extent, prior to the interlace diode should be avoided, as there will be a memory , or offset voltage, that is different between odd & even fields, just prior to the vertical sync pulse leading edge on odd & even fields.

My TV22 was set for a normal contrast image and the vertical hold set so the picture was rolling upwards just a little before it fell into vertical lock. (This is generally the better way to set a vertical hold control). Oscilloscope recordings were made of the following test points:



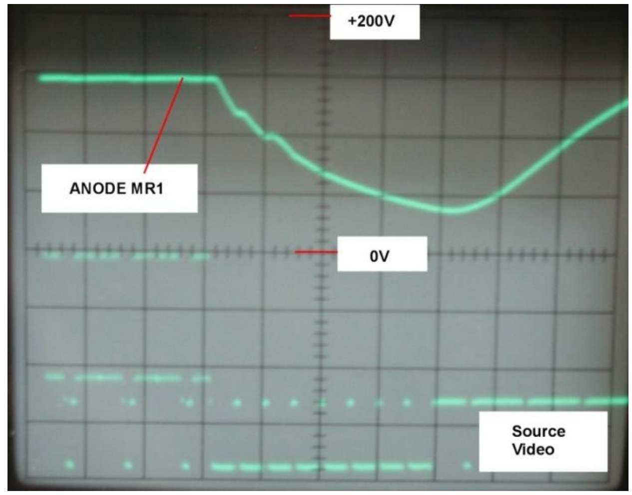
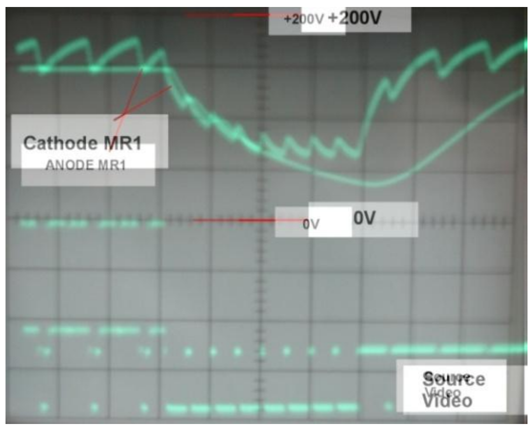


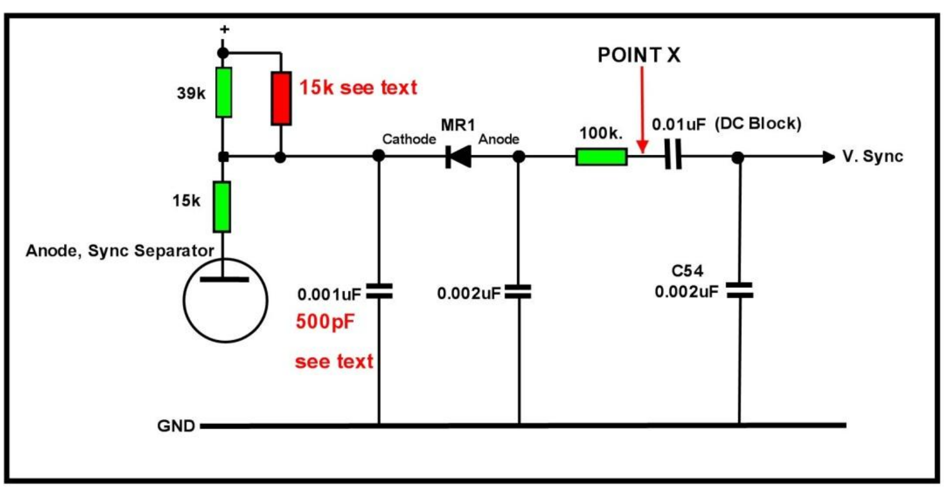
FIGURE 1.

Another recording of the two super-imposed:

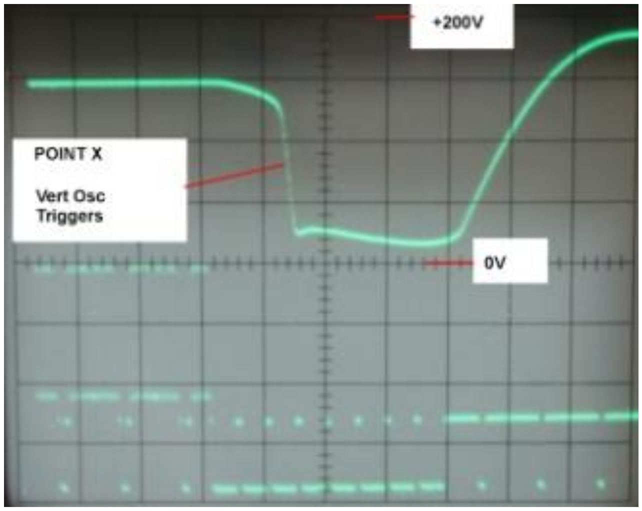


This shows that the diode starts conducting in the forward current mode only on the leading edge of the vertical sync.

The circuit is shown below. For it to work, MR1 must be a leaky diode, if it is replaced with a modern silicon type it requires a 1 to 2 Meg Ohm resistor in parallel with it for the circuit to work.

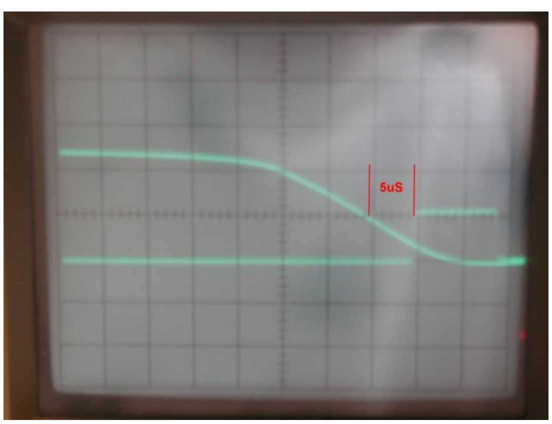


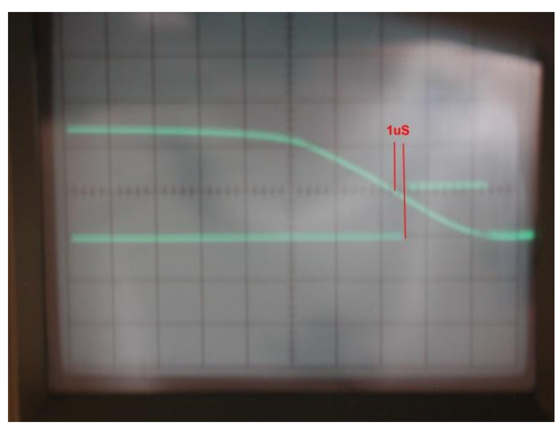
The recording at point X in the circuit is shown below:



Of note, the sudden negative going transient seen above at "Point X" is the result of the vertical blocking oscillator's plate voltage falling low (vertical flyback initiated) after being triggered by the vertical sync pulse. The blocking oscillator transforms the negative going sync pulse injected at the plate to a positive voltage at the grid, to synchronize the V oscillator.

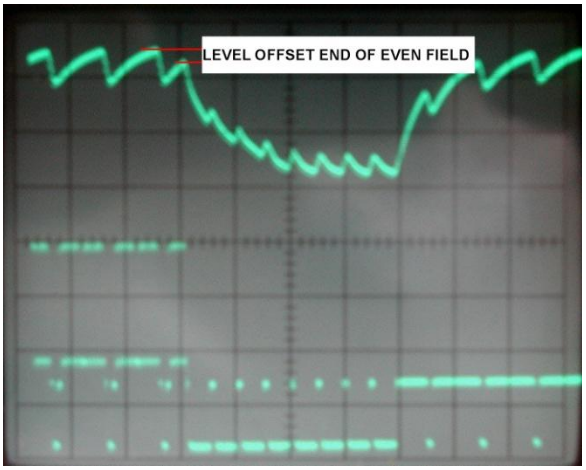
Close examination shows a timing error, which creates a 4uS or 9% interlace error.(Of note a 100% interlace error would be half a line period or 49us) These recordings show the timing of the vertical sync pulse leading edge with respect to an H pulse inside the vertical sync pulse, comparing odd & even fields:



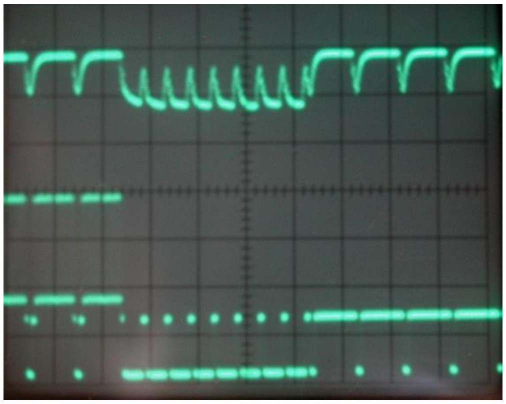


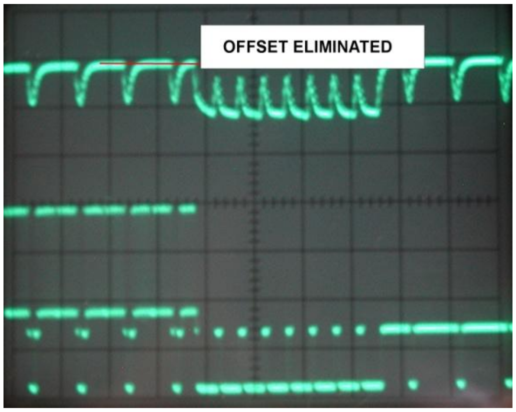
As can be seen there is roughly a 4uS error in the timing.

The reason for some of this error turned out to be in the sync separator stage. Due to the large value anode resistor 39k, combined with the 0.001uF capacitor, the integration of the composite sync was heavy enough that there was a different DC level on odd & even fields prior to the leading edge of the vertical sync pulse:

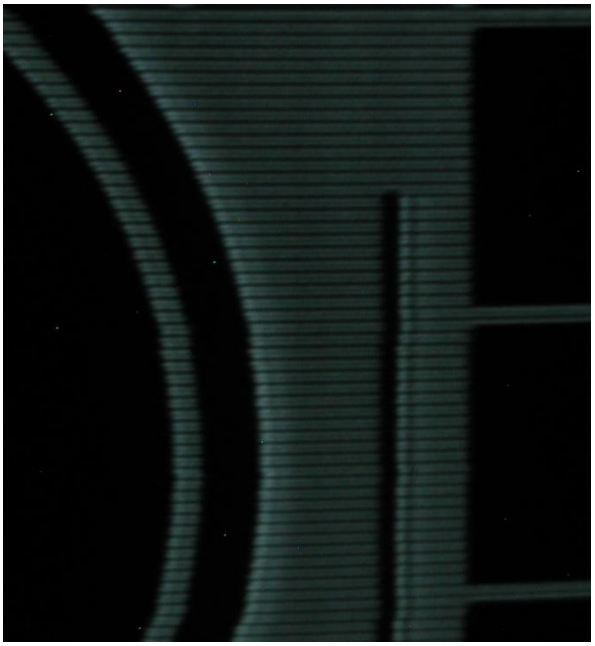


The fix was to parallel a 15k resistor with the 39k and lower the 0.001uF capacitor to 500pf, Then the voltage prior to the vertical sync is the same for both odd & even fields, because the now 500pF capacitor combined with the lower value of anode resistance charges up after the H pulse which is only half a line away from the vertical pulse at the end of the even field, to the same value as the end of the odd field, where the H pulse is a whole line away:

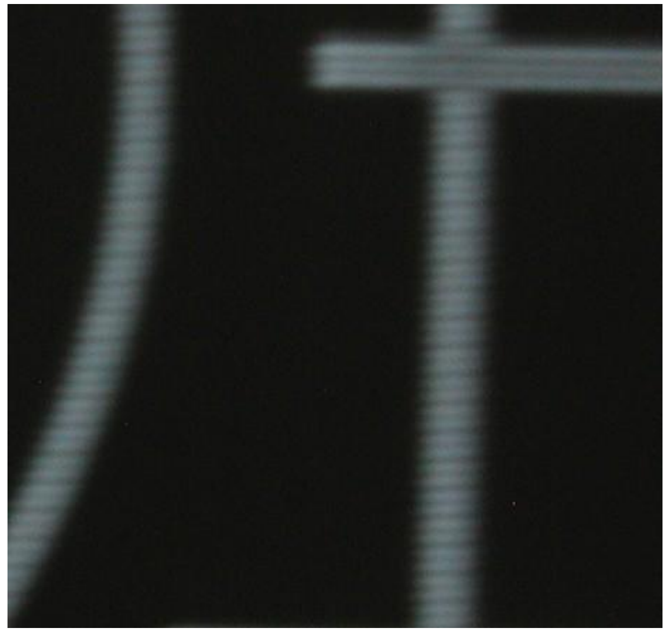




The following photo shows the interlace error on my TV22 before & after to the modification. The modification slightly improves but does not eliminate the error, but the line pairing is reduced a little to a more respectable level.



BEFORE



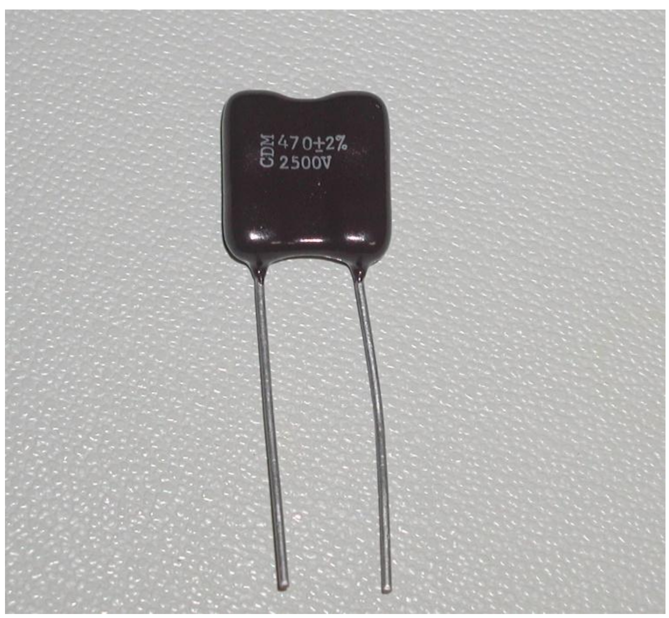
AFTER

THE 470pF LOPT TUNING CAPACITOR.

I thought this capacitor deserved a special mention. The original should always be replaced as it is generally degraded and problematic. If it fails it can stress the transformer.

It raises the interesting question of what kind of capacitor to replace it with. It must have a high voltage rating, at least 1000V and have very low losses. Note that the peak voltage across it in operation is 830V. But also it must be a *low loss* type, typical of the type of capacitors seen in RF circuitry.

A ceramic capacitor could be an option but sometimes these have poor temperature stability. A better type is the modern dipped Silver Mica, that is, if it has a suitable voltage rating. For my own TV22 I chose a 2500V rated type to be sure that failure was unlikely in the application. This is not a component that one should scrimp on or try to save money on.

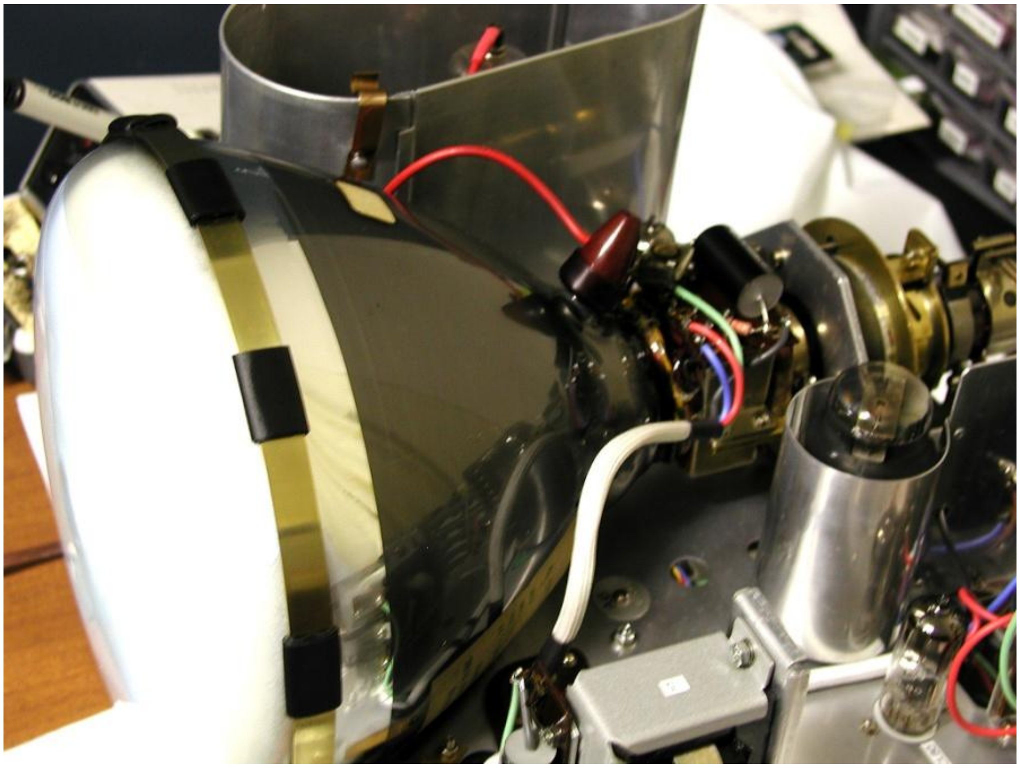


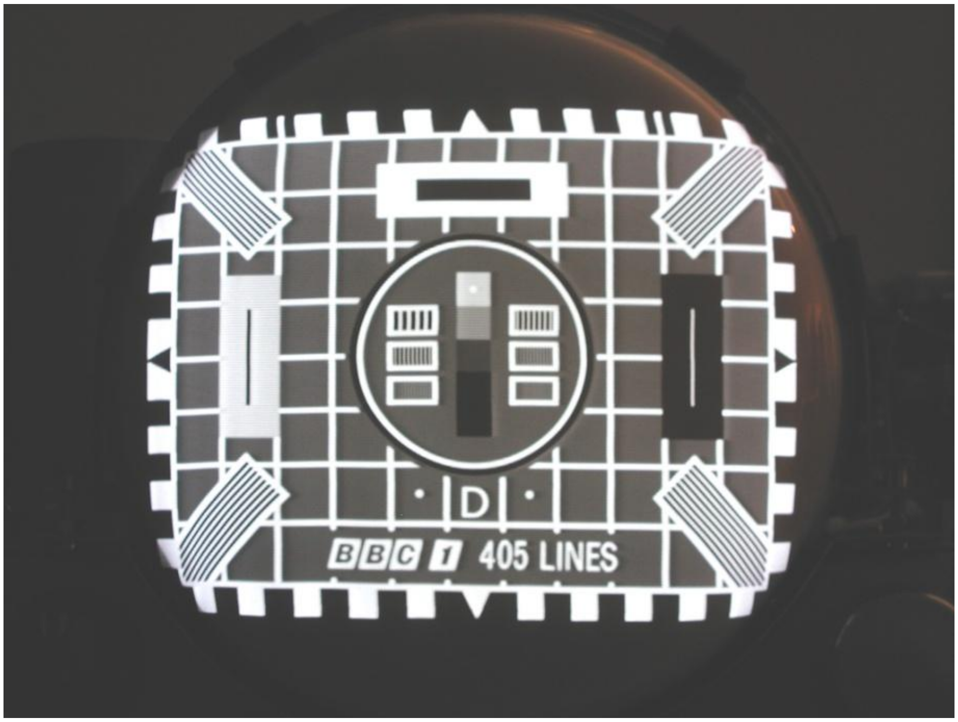
RESTORATION OF THE TV22:

Rather than writing a description of the restoration of my set as I have done for others, the pictures in this case tell the story. The set required complete dismantling & rebuilding with much attention to detail. The images simply show the post restoration results. This required extensive removal of rust & corrosion, refinishing of surfaces, cleaning and varnishing inductor windings, various components electroplated and painted and full rewiring and tube socket replacement to attain these results. Fertan organic rust converter was used to treat the rusty transformer laminations before they were re-varnished, it was not necessary to unstack any of them.

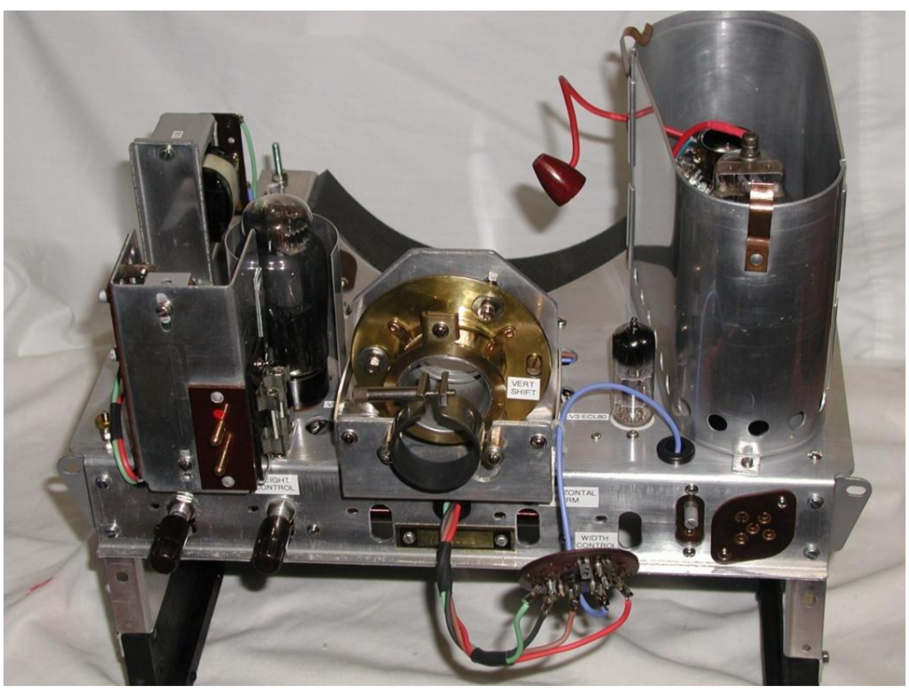
All new nickel plated brass & zinc plated steel BA hardware was used throughout. High quality capacitors and 2W metal film resistors used commonly throughout except where high power or higher voltage rated resistors were required.

The first image shows the top view of the restored chassis fitted with a CRM93 CRT. The second image is an un-touched screen shot of a test pattern generated by David Grant's 625:405 line standards converter fed to the set via an RF modulator:

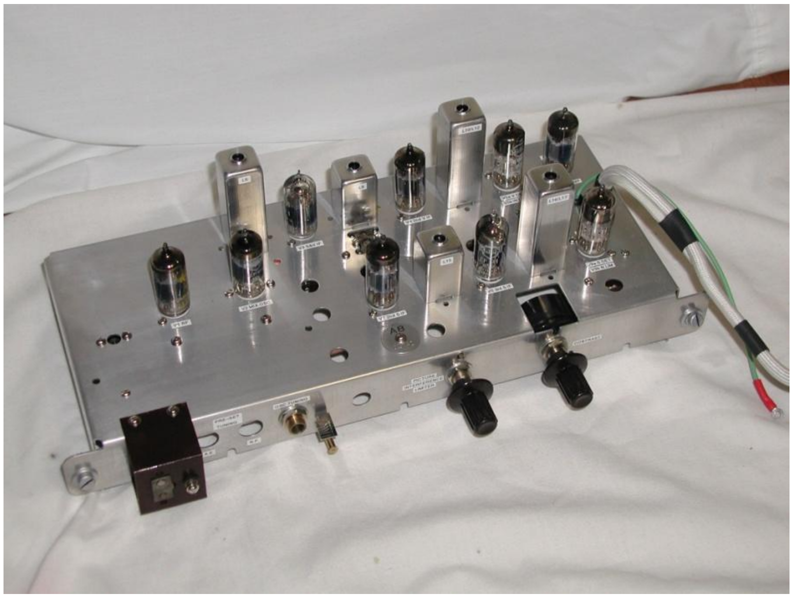




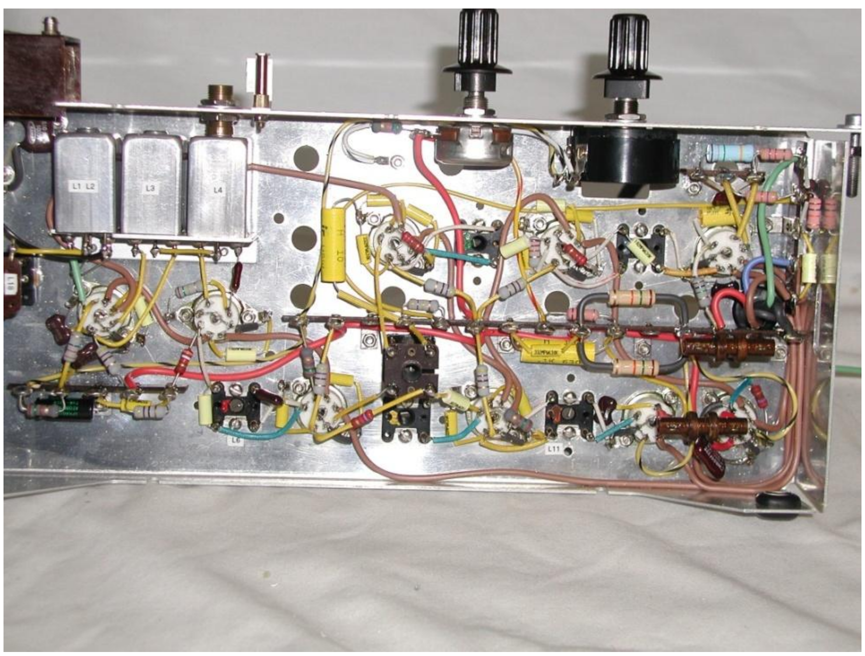
Upper chassis restoration:



Lower Chassis restoration: Labels have been added to identify tubes & controls and other components:



Underside lower chassis:

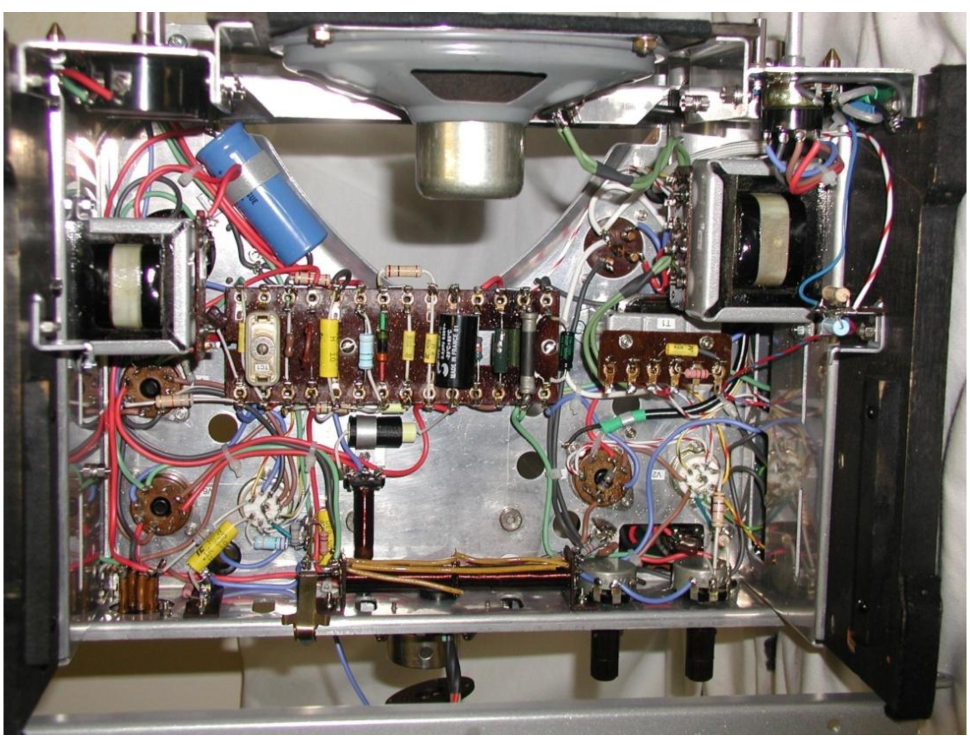


The original tuning control was missing from coil L4.

Finally, I was after many years able to find a replacement tuning knob & spring assembly from a fellow in the UK parting out a set.

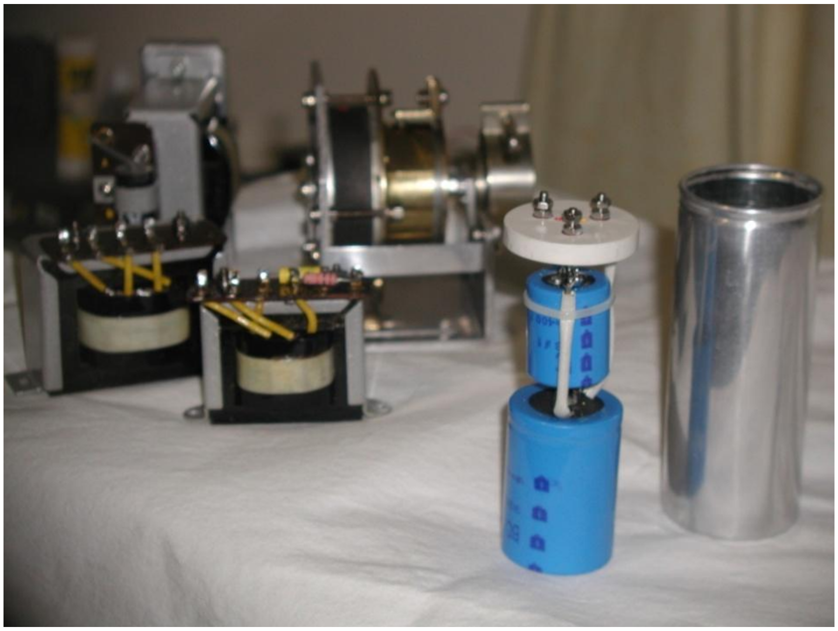
It is a very unusual tuning knob that is a combination of brass & ferrite to extent the possible tuning range of the local oscillator across 5 channels with, just the one tuned coil.

Underside upper chassis: New wiring is silicone rubber covered. New sockets ceramic for the small tubes. Original diode MR1 Westector type and the original Brimistor retained. A temporary speaker was borrowed from a transistor radio until the replacement arrived:

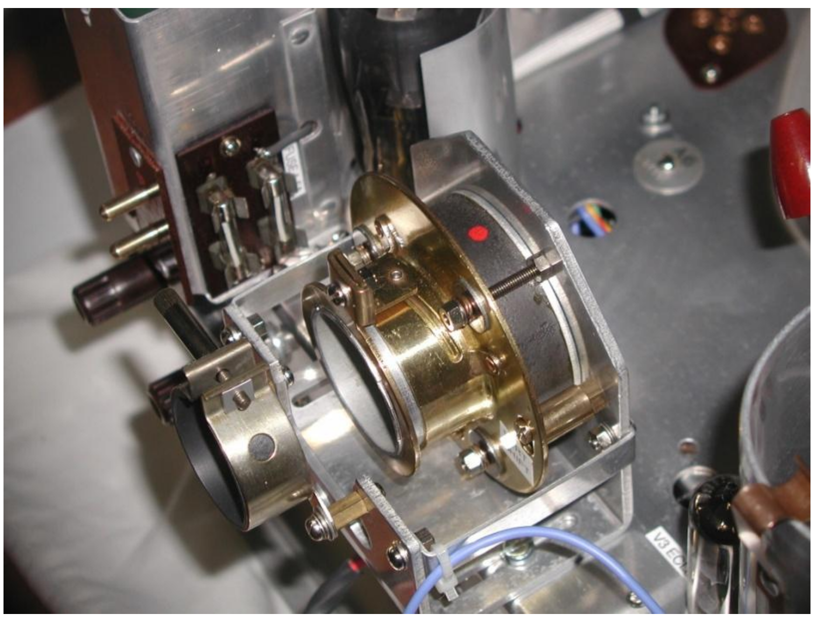


New Electrolytic Capacitors placed in old metal can. Transformers & chokes restored, the brackets were re-electroplated and painted to improve the appearance and protect them and the rusty laminations treated with Fertan and the transformers varnished:

The white material making the insulator/connection for the electrolytic is ¼ inch thick Bramite. Paxolin or 6mm thick fiberglass would also work. Notice how most of the lip on the large electrolytic's can is preserved. This is much better than cutting the aluminium can near its base, especially in this case where it is clamped near the other end in the set.

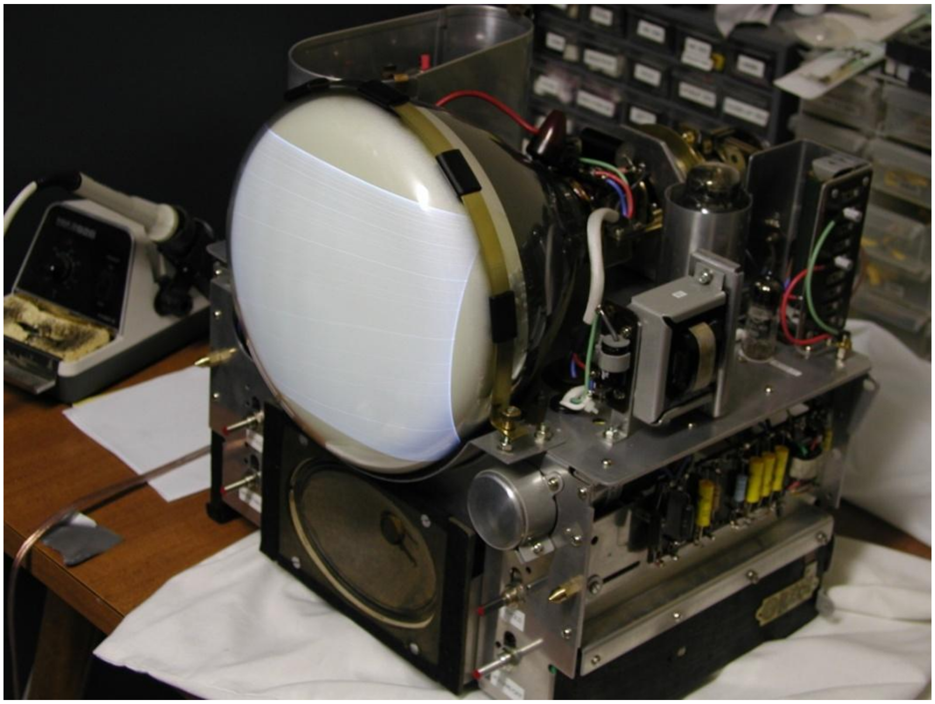


Focus magnet and CRT mount assembly:

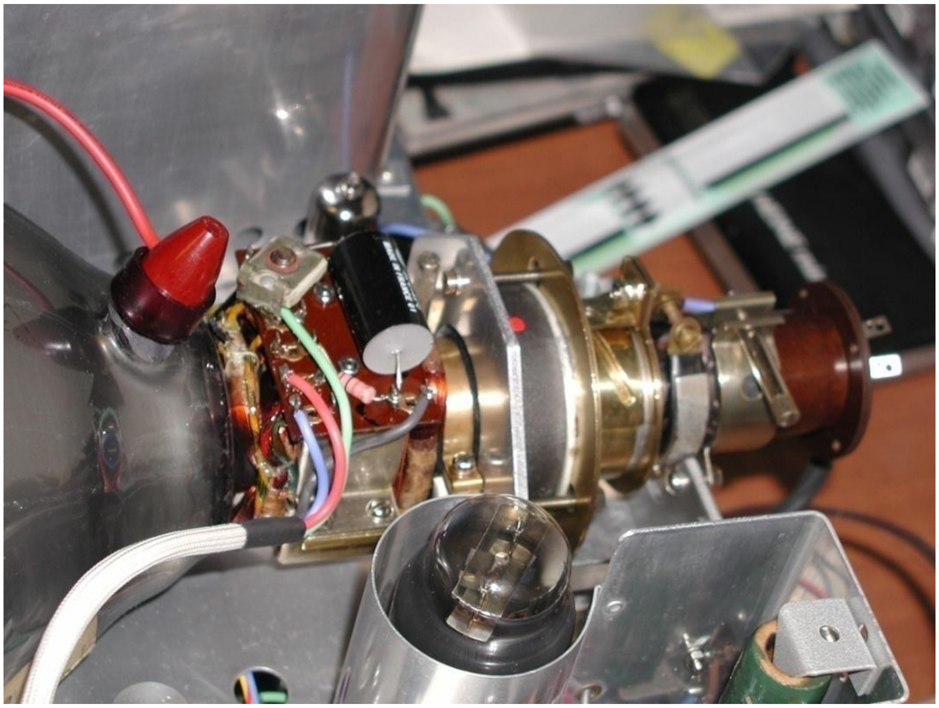


Of note, if the focus magnet assembly is disassembled, the magnets will lose strength. The assembly acts as a keeper. I have explained on the forums how to re-magnetize these assemblies with an external coil. Oddly nobody had tried this before and weak magnet assemblies were getting discarded. I first re-magnetized a weak focus magnet assembly back in the 1970's.

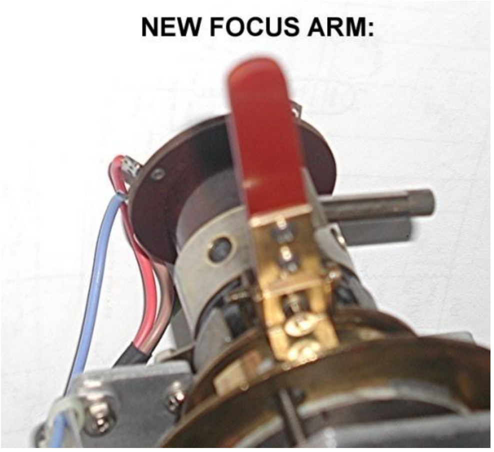
Chassis overview after restoration:



Deflection yoke assembly:



A new focus arm was made to replace the original out of brass and brown phenolic material, (ironically this image is out of focus)



Aonther speaker was fitted in the end:

Of note, a good place to monitor the Local oscillator frequency with a probe & frequency counter without significantly pulling the L/O frequency is at the junction of C10 & L6 (Trader sheet 1003/T15).

Also it is useful to have the L/O frequencies for each channel to check the L/O knob and its mechanical pointer are indicating correctly and tuning over the correct range of frequencies:

Channel 1…61MHz

Channel 2…67.75MHz

Channel 3…72.75MHz

Channel 4…77.75MHz

Channel 5…82.75MHz

My TV22 was realigned with the aid of a sweep generator, a good oscilloscope and a precision marker generator.

Note, the original 2uF electrolytic H coil yoke coupling capcitor was eliminated (it was a very bad choice to begin with) and replaced with a 2.2uF 630V rated Poly cap which will never give any trouble in the application.

Screen image via a 625 to 405 line standard converter/RF modulator gives an idea of the image reproduction that these sets were capable of:

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