SANYO's Amazing 8-P2 Tevelevision from 1962.

(H. Holden. July 2020.)

This article is a follow on in the series of portable early transistor TV sets that I have been writing recently.

Background:

The early 1960's was a boom time in the television industry for semiconductor based compact & portable TV sets. Many of these were able to be powered by either on board batteries or an external 12V supply. Valve TV's were rapidly becoming obsolete and "new and better transistors" started to be able to fill the role of valves in demanding applications.

As will be explained in this article, in a semiconductor based TV set, one of the most demanding applications is the horizontal scan output device. In a transistor set, it must have a very low saturation voltage drop during the horizontal scan time and also be able to withstand very high peak collector voltages during flyback and on top of that have a very low storage time, so as to be able to switch off rapidly to allow a fast flyback. Some of these features were difficult to achieve parameters for a Germanium device in the early 1960’s.

In another set, the Sony Micro 5-303E TV, released in 1962, they were well ahead of the game in transistor design. Sony had already moved to Silicon transistors for the horizontal and vertical scan and video output stages. Not all companies were this advanced, but, the Germanium transistor technology was still up to the task.

It also seems that one of the most acclaimed early TV's was Sony's 8-301W, said to be one of the world's first miniature TV sets that was all (well nearly all) transistor, it had tube EHT rectifiers, albeit just beaten to the market by the Philco Safari in the USA.

Though there is little talk of a very similar TV set from around this time, the 1962 vintage Sanyo 8-P2, the same size as the Sony 8-301W and the same age as the Sony 5-303E, it does not contain a single silicon transistor.

The Sanyo 8-P2 TV educated me on transistor television design:

I was given the Sanyo 8-P2 by an elderly retired TV technician in 1975 or thereabouts when I was about 17. He was "Valve TV trained" and never warmed to the notion of transistors. Though he was very smart and had built a number of his own valve TV sets.

This particular set was faulty and the horizontal output transistor, which had been replaced, just sat there heating up with no EHT and no horizontal deflection. The assumption was that the LOPT had failed. The original physically gigantic damper diode (energy recovery diode) was missing and a silicon rectifier substituted in.

After some research at the time I worked out that the original PNP germanium transistor had special properties, including low capacitances, a high transition frequency, a fast recovery time and the ability to withstand very high collector voltages and work well as a saturated switch. No internet back then, so it sometimes took a while to acquire transistor data.

The TO-3 cased transistor which had been substituted in for the original type was an unsuitable type intended for audio frequencies. After a while I was able to source a 2N3731 and get the set "working" again. The 2N3731 is a PNP Germanium power transistor designed by RCA specifically for TV Horizontal deflection applications and has astonishing specifications for a germanium device:

Peak collector to base voltage -320V, 10A collector current and a turn off time of 1.2uS and a high maximum junction temperature, for a germanium, of 185 Deg.C which is very unusual.

This transistor could support 114 degree deflection applications and could support a peak yoke current of 10A and turned off more than fast enough for the about 12uS retrace or “flyback time”.

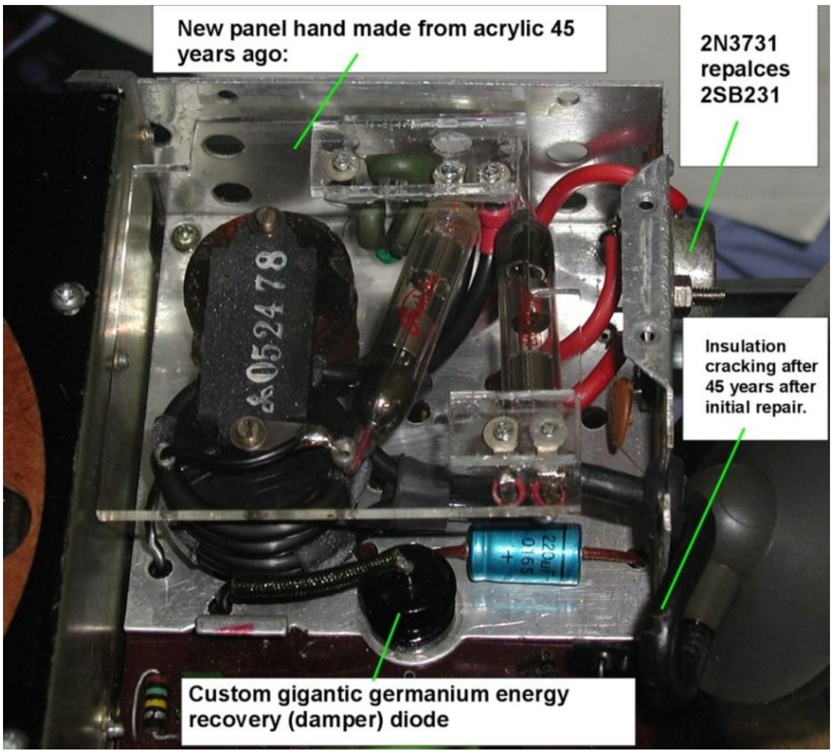
RCA also manufactured a companion Germanium Damper diode, the 1N4785.

At the time I knew of no source for a replacement germanium damper diode, except for the RCA 1N4785, which I did not have and no Ebay back then either.

Later I would learn about the diode type DG14TV, used in Australian made AWA portable TV sets and another diode type the AY102 which both would have worked. It is likely that the DG14TV is merely a re-labelled 1N4785. Finally, from a wrecked Sanyo 8-P2 set a year or two later, I found one of the original gigantic germanium damper diodes.

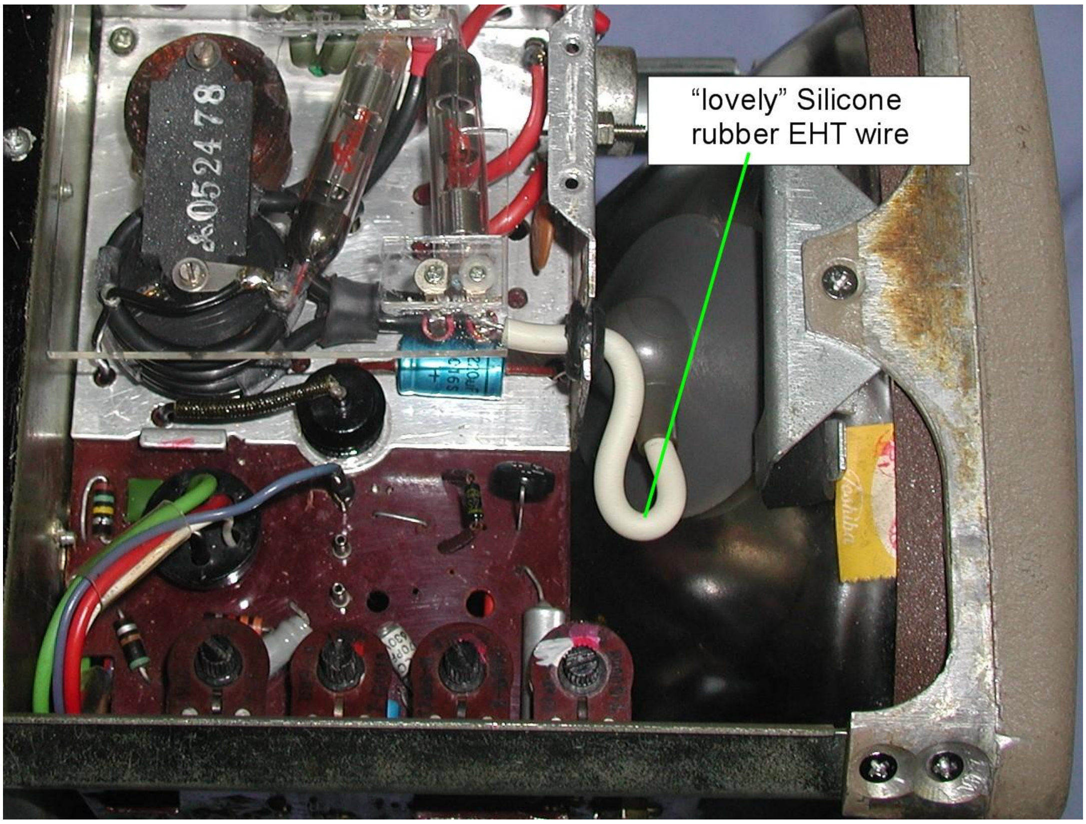
I installed the 2N3731 in the set, recapped the set (except for the large main power supply filter capacitors) and this is when the fun began.

After a while the phenolic plate that supported the two tube EHT rectifiers became conductive with arcing on its surface. So to fix that I hand crafted a new plate out of acrylic, this repair is around 45 years old now and it still looks ok:



There appears to be a Mitsubishi Logo on the LOPT core in this set. Sanyo must have acquired it from them. It is the only place inside this set where this logo occurs.

It is interesting that the rubber covered EHT cable, which I had replaced back in the 1970's has now started to crack, so I replaced it again, this time with very high quality white silicon rubber covered wire. As a teenager I did not have access to good wire like this back in the 1970's:

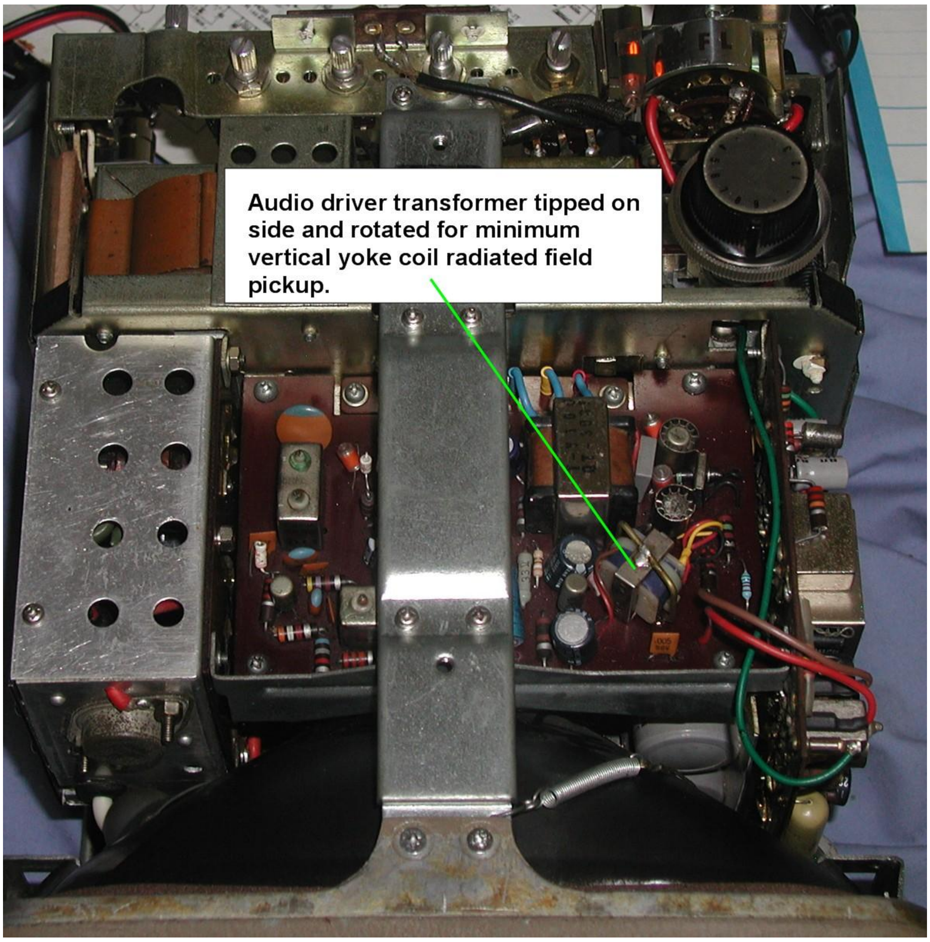


Once the horizontal scan and EHT system was up and running I was able to sort out some other problems in the set.

It was working on this TV set that I learnt the art of sweeping the video & audio IF's with a sweep generator and scope and putting the set into good alignment and I was generally pleased with the performance of it.

There was an annoying vertical buzz in the audio caused (after a lot of investigation) by the audio driver transformer core picking up radiated magnetic fields from the vertical yoke's coils. The audio amplifier and audio IF board being mounted fairly close to the yoke.

The designers must have been aware of this as they had the transformer at an odd angle on the pcb. But I found that by tipping it on its side and rotating it to a very specific angle I could reduce or null the interference to a very low level. So I fitted a small brass hoop on the old bracket mounting and soldered the transformer to the better angle. Of course later, when inter-stage transformers got abandoned in audio amplifiers, this potential problem also vanished.



But, there was something that troubled me, the horizontal scan linearity was stretched (expanded) at the beginning of scan on the left and looked reasonable elsewhere. It was much worse with the replacement silicon damper diode and improved to a fair degree when the original type of germanium damper diode was fitted. It would take me some years to know the cause of this issue.

This set has an S correction cap in series with the yoke H coils, but no width control inductor and no magnetic linearity coil. The width can be altered to a degree by tightening or loosening the clamp screws on the H output transformer, however, better linearity is acquired with them tightened up. The S correction capacitor in this set is a high quality, low ESR, 7uF oil filled type. There was nothing I could adjust that affected the horizontal scanning linearity. I held on to the set for many years and recently power it up again, after about a 40 year interval.

The set "almost worked" on re-powering it recently. One of the five or so 2200uF clamp mounted electrolytic capacitors (which I had not originally replaced) promptly failed by heating and gassing out.

One interesting this was that the ESR, uF value and leakage on a low voltage test of all of these old large 1" diameter capacitors looked ok on my meters.

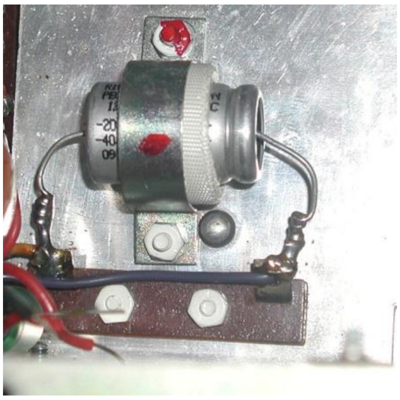
However, when the applied voltage got over about 10 to 11V, then they abruptly started to draw current & heat up. It just goes to shown that apart from the usual tests we do on electrolytic capacitors, to help verify their performance, they should always be checked for leakage just inside their rated voltage.

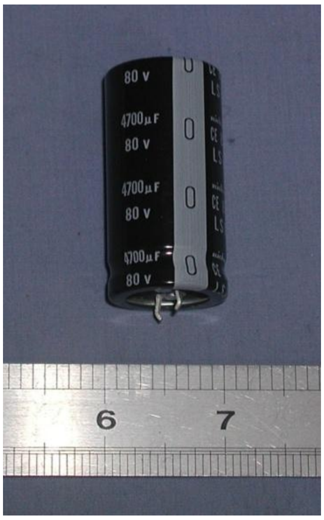
I therefore replaced all of the large 1" diameter clamp mounted capacitors in the set and also the Vertical yoke coil's coupling capacitor.

Photos of the old original Sanyo capacitors and they were fairly generous with the number they used. The set requires good filtering of the power supply as there is no electronic regulator for the 12V supply, merely a transformer and bridge rectifier when running from line power. The larger 500uF axial electrolytic in the photo is the Vertical yoke coil's coupling capacitor.

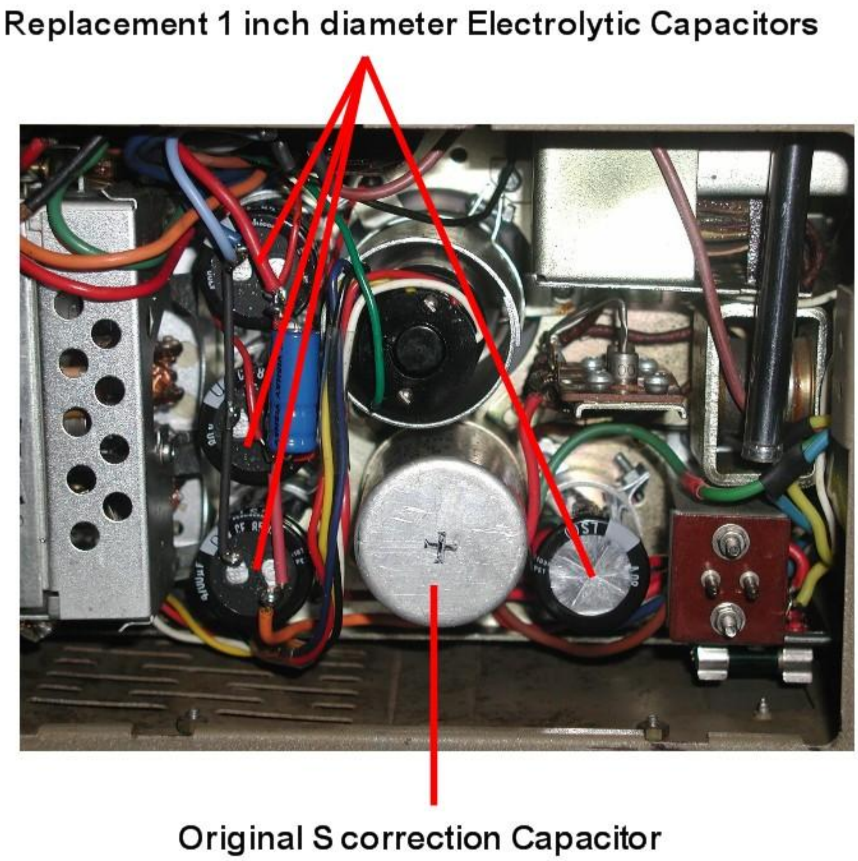
The capacitors in the photo are very physically large for the voltage and uF values compared to modern day equivalents which have about 1/5th the volume or less.

The CRT required removal from the set to replace the 500uF 12V rated vertical Yoke coupling cap. I replaced this one with a 125 Deg C 40V rated 1000uF Rifa Automotive rated capacitor that will never likely need replacing. I replaced the 2000uF 15V units with 4700uF 80V Nichicon types. This was the closest I could find with a large enough 1" diameter canister size to approximate the original appearance. The extra capacity is not unhelpful running from line power and improved the noise rejection running the TV from a 12v switch-mode psu too.



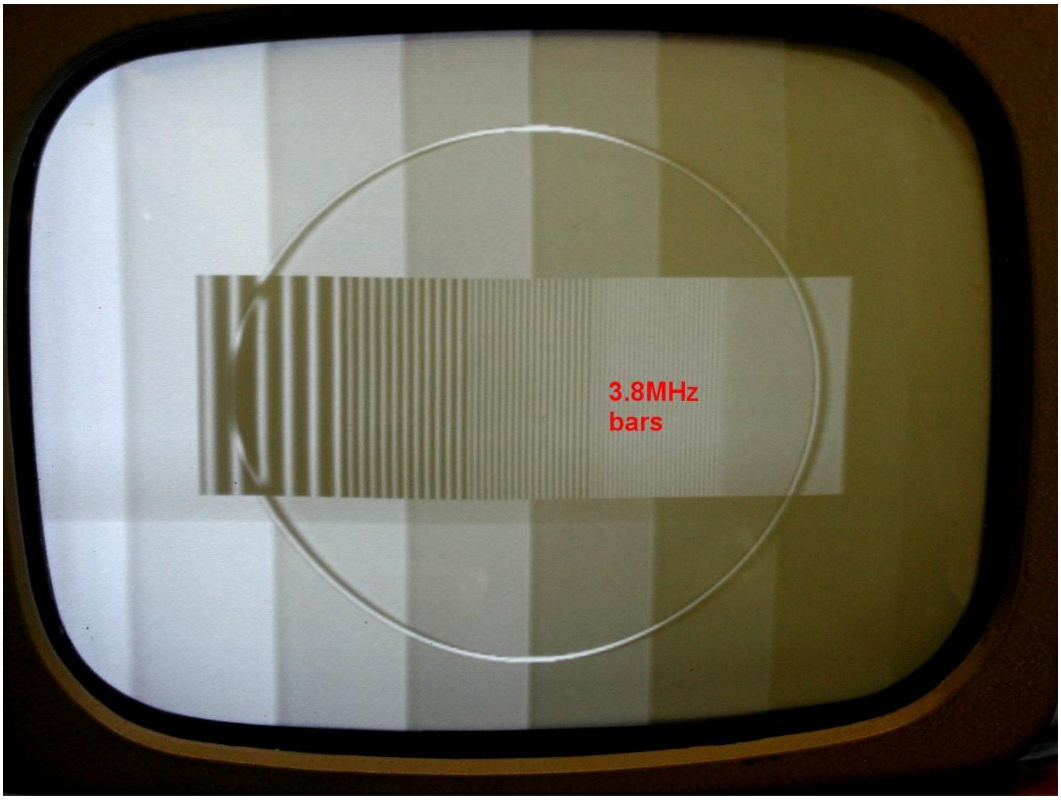


The photo below shos the replacement 1 inch diameter capacitors on the rear chassis. This is the view into the battery compartment. This compartment once held, of all things, a 12V wt Lead Acid cell, much like a small motorcycle battery.



Performance of the Sanyo 8-P2:

The high frequency video performance of this set is reasonable, the photo below shows when its tuned in properly the 3.8MHz bars are just visible, which is an adequate resolution for the 8 inch screen:



Horizontal scan linearity issues in early transistor TV's:

Two terms are used in this discussion; *expanded & compressed* linearity:

In this case *compress*ed linearity means cramping of the horizontal picture elements together along some part of a horizontal scan line, due to a slower moving electron beam, in other words a yoke scanning current that has a lower rate of change with time than the areas around it on the horizontal scanning lines. *Expanded* linearity means the picture elements are seen stretched apart due to a faster moving electron beam with a higher rate of change of yoke current with time than the areas around it.

In addition, though it might not be too obvious, in a TV or any other electronic apparatus, which runs on a low power supply voltage compared to another set, by necessity, any circuit currents must be higher for the same power level. This makes any effects of circuit resistances more significant.

The magnetic fields generated by the TV's deflection Yoke's Ampere-Turns must be about the same for a given amount of deflection of the CRT's beam in either a tube or transistor based set. Therefore an interesting design challenge crops up. The peak yoke currents in a 12V powered set need to much higher than in a higher voltage operated set, for the same deflection power, yet the yoke winding Ampere-turns must be similar.

This created a need for the Yoke’s winding wire (especially for the Horizontal yoke coils) be made of thick low resistance wire, yet thin enough to physically wind into a formed Yoke coil to get enough Ampere-turns.

As will be shown, in 12V operated sets, resistance in the Yoke H coils degrades the horizontal linearity, causing compressed linearity of the scan on the right side of the raster and stretching on the left. It took me some time to realize exactly why this was the case.

In transistorized TV’s, the horizontal scan output stage acts as a switch, and the rate of rise of current is dependent on the L,C and R properties of the horizontal yoke coil and horizontal output transformer. The horizontal scan linearity is not modifiable by altering the drive waveform to the Horizontal output transistor. (This is unlike the case in the vertical scan stages which act more or less like their audio amplifier counterparts and the drive waveform shape to the output stages controls the vertical scan linearity)

This horizontal scan linearity problem, was largely solved or ameliorated in the early solid state TV’s with horizontal yoke windings that were “quadra-filar” wound or sometimes up to 6 strands of wire to help keep the DC resistance of the horizontal yoke’s coils low, while still being able to physically wind and form the shape of the yoke coils.

Later, the horizontal scan linearity in transistor TV sets and computer VDU’s was manipulated with a combination of “S correction capacitors” and magnetically saturable inductors (with a permanent magnet) in series with the H yoke coils.

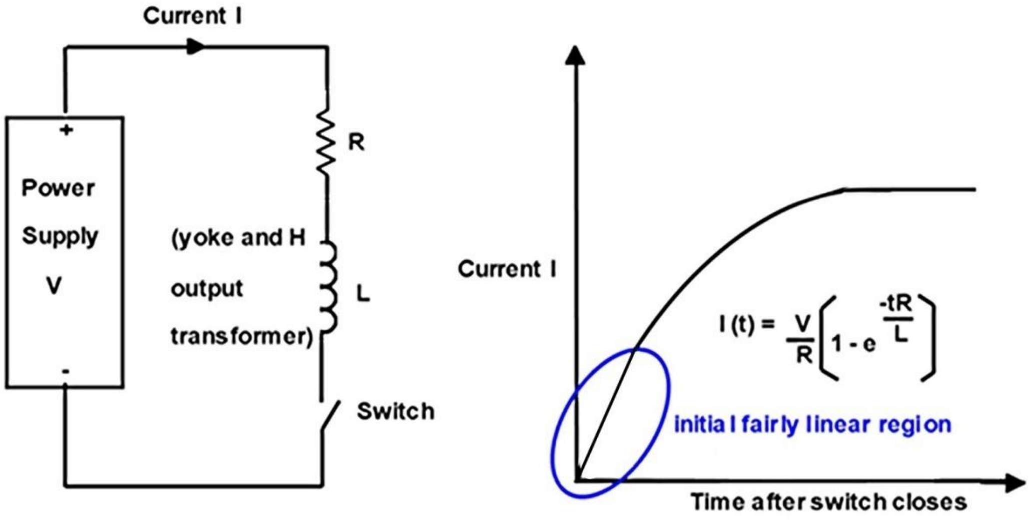
Close inspection though will show that most 12V operated TV’s of the very early 1960’s will show expanded scan linearity on the left hand side, with no adjustment inside the TV set which can alter it. The technical explanation is given below:

When a fixed DC voltage is applied across an L-C-R circuit, the current rises initially linearly with time and flattens off in the usual inverted exponential manner.

Initially at least, when an un-energized inductor is switched across a power supply , the rate of rise of current is linear and rises at a rate of V/L Amps per second, where V is the power supply voltage and L the inductance.

(This is found by differentiating the usual equation for the inverted exponential current wave and solving for $t = 0$).

Notice that this very initial linear rate of current rise does not contain the variable R. The graph below shows these features:



Initial rate of change of current $= \frac{dI}{dt} = \frac{V}{L}$ Amps/second

The yoke's coils and the power supply for that matter are not free from resistance, so as time passes the rate of rise of current flattens off (in the usual inverted exponential form) and settles to a value of V/R amps and in this case the variable L has now vanished.

In a TV set's horizontal deflection system, the proportions of yoke inductance, resistance and power supply voltage are chosen so that mainly the first part or "near linear part" of the current rise is used, to scan the CRT's beam from the centre toward the right hand side of the CRT's faceplate.

On the right hand side of the scan (with no other corrections) sometimes compressed linearity is seen as the rate of rise of current with time is tapering off due to the inverted exponential form of the current rise.

However, a small amount of this right sided compression is helpful, for the reason that the sensitivity of the yoke (sensitivity being the amount of change in beam deflection it gives for any amount of change on yoke current is higher with higher deflection angles) is higher for higher angles of beam deflection.

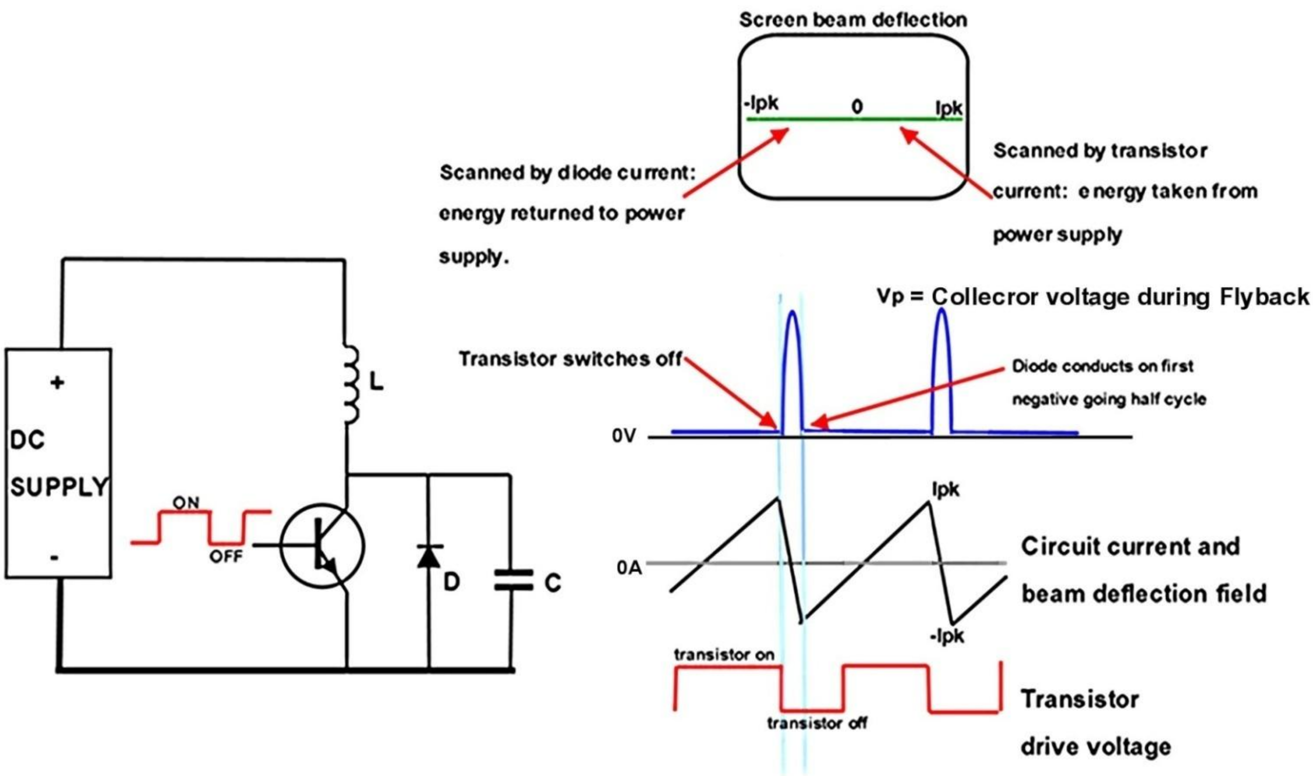
Therefore the tapering rate of rise of current with time, towards the extreme right hand side of the scan, due to the L & R properties of the yoke, tends to cancel this sensitivity effect, on that side of the scan. Often not completely cancelled though, see below in discussion on "S correction capacitors" often still required.

The bottom line is, it is fairly easy to achieve reasonable horizontal scan linearity, in a 12V operated transistor, especially for small screen sizes and low range deflection angles (even without a magnetic linearity coil or S correction capacitor), from the central part of the scanning raster, to the full deflection on the right hand side. Provided of course the Yoke's L and R values are suitable. However, the left hand side of the scan and its linearity is much more difficult.

The diagram above shows a typical simplified Horizontal deflection system, with a switching transistor, a damper diode, an inductance L, representing the horizontal yoke coils and a tuning capacitor C, which tunes the flyback frequency, of which only a half cycle is seen.

The transistor's current scans toward the right side of the raster, the damper diode current scans the left hand side, the peak horizontal yoke currents Ipk and -Ipk are indicated.

The idea is very old and is the basis of some modern SMPS power supplies. The stored *energy* in the magnetic field of the yoke and the associated horizontal output transformer, at the end of each horizontal scan line, on the right hand side, is given during flyback (initiated by the switch opening or the switching transistor cutting off) to the electric field energy of the tuning capacitor. All this energy is in the capacitor's electric field half way through the flyback pulse, when the voltage on the capacitance peaks.



At this point , half way through flyback, all the stored magnetic field energy has been given to the capacitances, the yoke current is zero and the beam at the CRT's centre position. The flyback voltage pulse is seen as a half cycle of high voltage oscillation on the transistor's collector terminal, over the flyback time of typically around about 12uS. These peak voltages can be in the range of 100V for a small monochrome TV and over 1kV in a large colour TV.

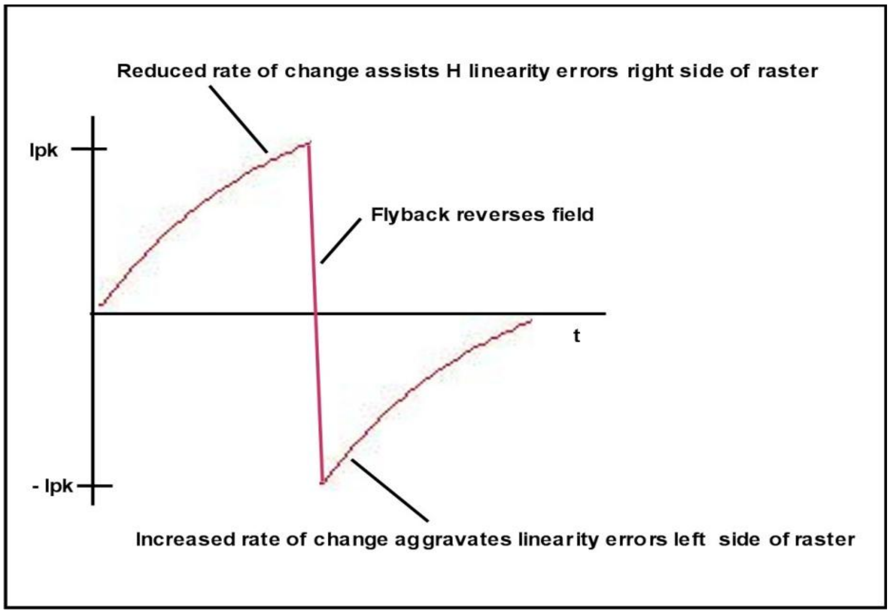
One major consequence of the flyback period, is at the end of the flyback time, just prior to the flyback voltage pulse attempting to go negative and when the capacitor's energy has been returned to the magnetic field energy of the inductances and the capacitor's voltage and energy are zero;

Both the direction of the current in the yoke and the polarity of the magnetic field have been reversed and the CRT's beam is now at the left ride of the raster, ready to scan the next line.

The initial line scanning current, after flyback, on the left hand side is achieved when the damper diode (energy recovery or efficiency diode) is pushed into conduction and the magnetic energy of the inductances are returned to the power supply in a controlled and again, *inverted exponential* manner.

However, in this case, unfortunately, on the left hand side, the damper diode's current tapers off with time toward the scan centre*, starting with an initial high rate*, rather than having a tapered or lower rate of change at the start of the scan on the left hand side (which would be ideal to mirror the shape of the current wave on the right hand side). This effect aggravates, rather than cancels the Yoke's sensitivity issue for high deflection angles, as it does on the right side. The result is expanded linearity on the right hand side.

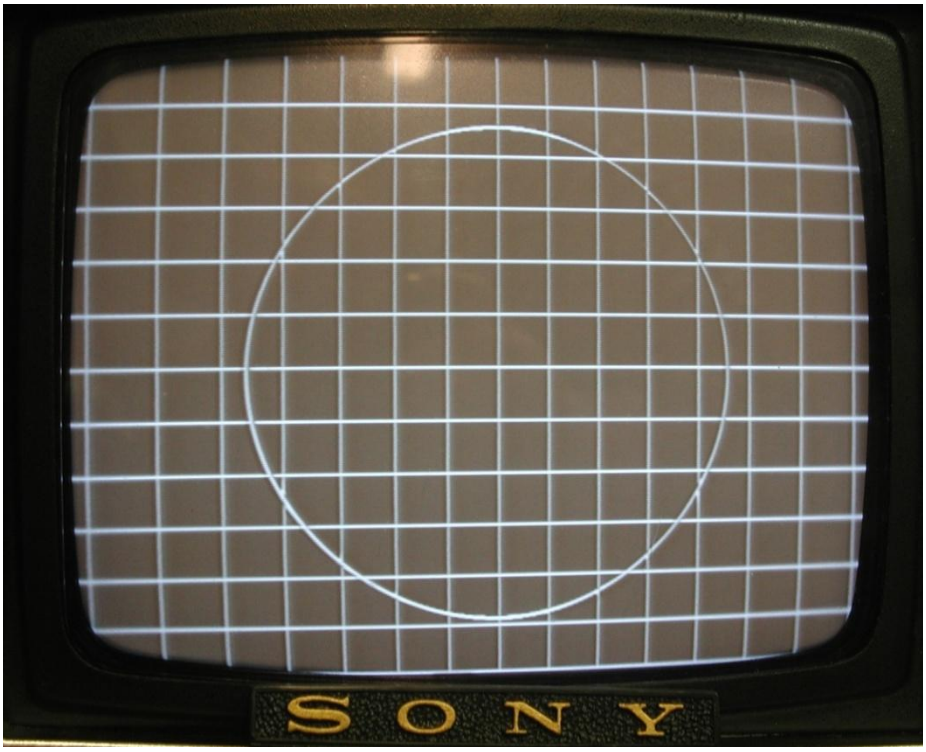
Therefore, without any *linearity correcting components*, the horizontal scan will have expanded linearity on the left hand side. The graph below indicates the features explained above:



The image below shows the horizontal linearity on the Sony Micro-TV, inspect the horizontal linearity very closely because:

The Sony Micro-TV makes an excellent case in point to study horizontal scan linearity issues because the horizontal linearity result it produces is devoid of any linearity correcting components (neither an S correction capacitor nor a magnetic linearity coil).

Its horizontal scan linearity properties show beautifully the intrinsic asymmetry of the linearity at the end of the line scan on the right with respect to the linearity on the left (as shown in the graph above) but on top of this it also demonstrates the deflection sensitivity issue with the yoke, showing the average central compression of the linearity, compared to the sides.



SONY 5-303E

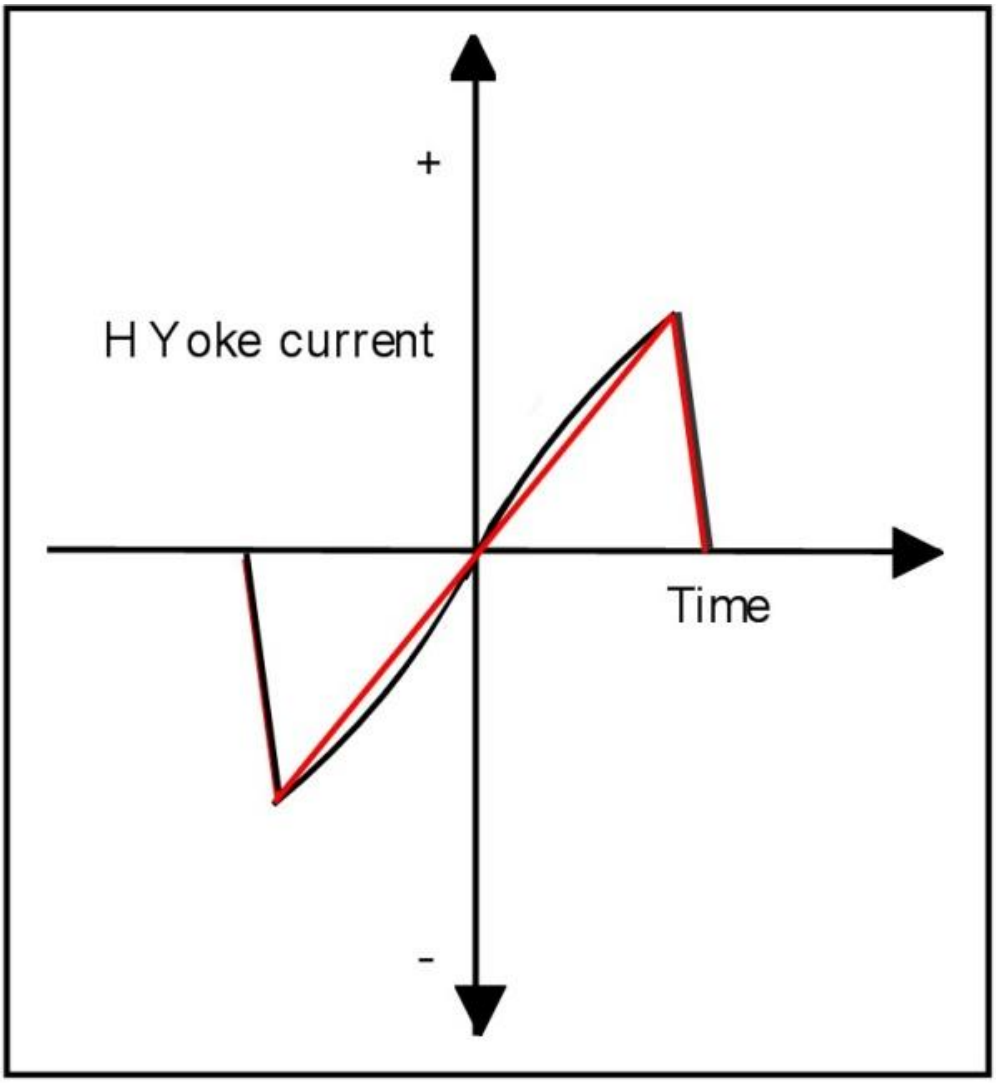
Close inspection therefore is expected to show, and it does, that the vertical lines are compressed together a little at the centre area, slightly expanded with respect to that on the right hand side and significantly expanded on the left hand side of the image.

The traditional method which is used to correct the centre horizontal scan linearity, with respect to the linearity at the sides is the “S correction capacitor” placed in series with the horizontal yoke coils. The Sanyo 8-P2 has this capacitor (even though the Sony micro-TV of the same year did not)

S correction capacitors are used to effectively expand the linearity near the screen centre area compress it toward the edges on the *right and left side* of the scan.

This is done by the S correction capacitor forming a resonant circuit with the inductance of the yoke coils to produce partial sinusoidal current wave.

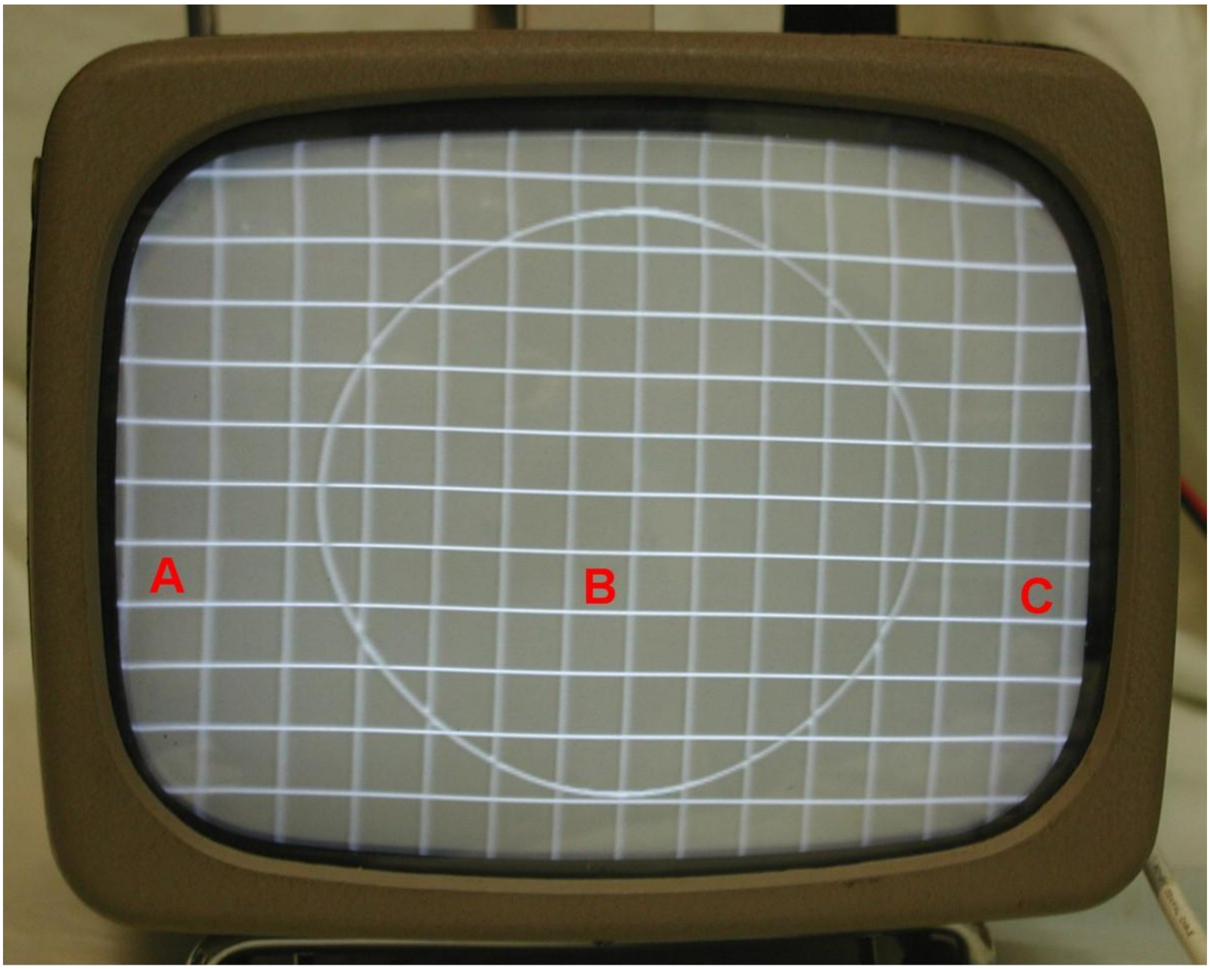
The effect of the S correction capacitor (black line in diagram below) when present, alters the linear yoke current (red in the diagram), if it was perfectly linear sawtooth current beforehand:



The S correction increases the rate of change of current with time near the centre of the scan, expanding the linearity there and compressing it at the right hand side and left hand side. One other advantage of an S correction (or another coupling capacitor) in series with the Yoke's coils is that is isolates any DC voltage present. This means that the return point of the yoke connections could either be to the 12V supply or to ground.

A photo of the linearity of the image on the Sanyo-8P2 with its S correction capacitor:

As noted here, unlike the Sony Mirco-TV, the horizontal linearity of the central area of the screen B, is very similar to that near the right hand side C (thanks to S correction), but still expanded in the region A on the left hand side, due to the magnetic field reversal and the shape of the current wave ae.



SANYO 8-P2

The left side expanded linearity relates, as noted before, to the shape in the current wave after flyback aggravating the linearity, rather than helping it and also another factor related to the circuit resistances.

It was noted before that any resistance in the yoke degrades the horizontal linearity. When the right hand side of the raster is scanned, the current pathway to the power supply has the very low dynamic resistance of a saturated switching transistor.

On the other hand, the left hand side is scanned by the current passing through the damper diode back to the power supply.

Often, in many Horizontal output stage designs, the damper diode is not connected directly to the same point as the collector of the output transistor and shown in the circuit model. A small tap, a few turns away on the output transformer helps to bring the damper diode into conduction a little earlier and helps to ensure that the transistor's collector is prevented from going negative (in the case of an NPN output transistor) with respect to its emitter.

Regardless of the presence or absence of an S correction capacitor, due to high range horizontal yoke currents in TV's running from low range power supply voltages and the high peak horizontal yoke coil currents associated with that, horizontal scan linearity in early 1960's vintage TV's was always an issue, depended very much on the Yoke design and its DC resistance, until later when magnetically saturable inductors were added in series with the yoke coils which allowed asymmetrical adjustment of the scan linearity.

In the case of the Sanyo 8-P2 the horizontal scanning linearity defect on the left side could be eliminated with the addition of a magnetic linearity coil, however, I decided to leave it as it was designed.

Also, in the case of the Sony Micro TV, I can see why they did not add an S correction capacitor. While it would have reduced the relative linearity errors from the screen centre area to the right hand side of the scan, it would have made the linearity defect on the left hand side more obvious. As it stands with that set, the horizontal scan errors overall look better averaged out.

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