VINTAGE TELEVISION

Sanyo's 8-P2 TV (1962) and horizontal linearity

By Dr Hugo Holden

The early 1960s was a boom time in the television industry, as semiconductor-based compact and portable TV sets were gaining in popularity. Many of these could be powered by either onboard batteries or an external 12V supply. Valve TVs were rapidly becoming obsolete, and transistors started to fill the role of valves in demanding applications.

One of the most demanding roles in a semiconductor-based TV set is that of the horizontal scan transistor.

It must have a very low saturation voltage drop during the horizontal scan time, be able to withstand very high peak collector voltages during flyback and have a short storage time, so it can switch off rapidly to allow a fast flyback. Some of these features were difficult to achieve for a germanium device in the early 1960s.

In the Sony Micro 5-303E TV, also released in 1962 (to be described in an upcoming article), 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.

One of the most acclaimed early transistor-based TVs was Sony's 8-301W, said to be one of the world's first nearly all transistor-based miniature TV sets (it had valve EHT rectifiers). However, it was just beaten to the market by the Philco Safari in the USA.

But there is little talk of the Sanyo 8-P2 of the same vintage. Despite it being 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. It was given to me by an elderly retired TV technician in 1975 or thereabouts, when I was around 17. He was valve TV trained and never warmed to the notion of transistors, even though he was very smart and had built a number of his own valve TV sets.

Faults

This particular set was faulty. 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 line output transformer had failed. The original physically gigantic damper diode (energy recovery diode) was missing, and a silicon rectifier had been substituted.

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 worked well as a saturated switch. There was no internet back then, so it sometimes took a while to acquire transistor data.

The TO-3 cased transistor which had been substituted for the original type was unsuitable, as it was only intended for use at audio frequencies. Eventually, 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. It has astonishing specifications for a germanium device: a peak collector-to-base voltage of -320V, a 10A maximum collector current, a turn-off time of 1.2μs and a high maximum junction temperature, for germanium,

The original repair (now 45 years old!) did not need many changes initially before testing.

of 185°C which is very unusual.

This transistor could support 114° deflection and switched off more than fast enough for the approximately 12μs retrace or 'flyback' time. RCA also manufactured a companion germanium damper diode, the 1N4785.

Remedies

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 of course, there was no eBay back then either).

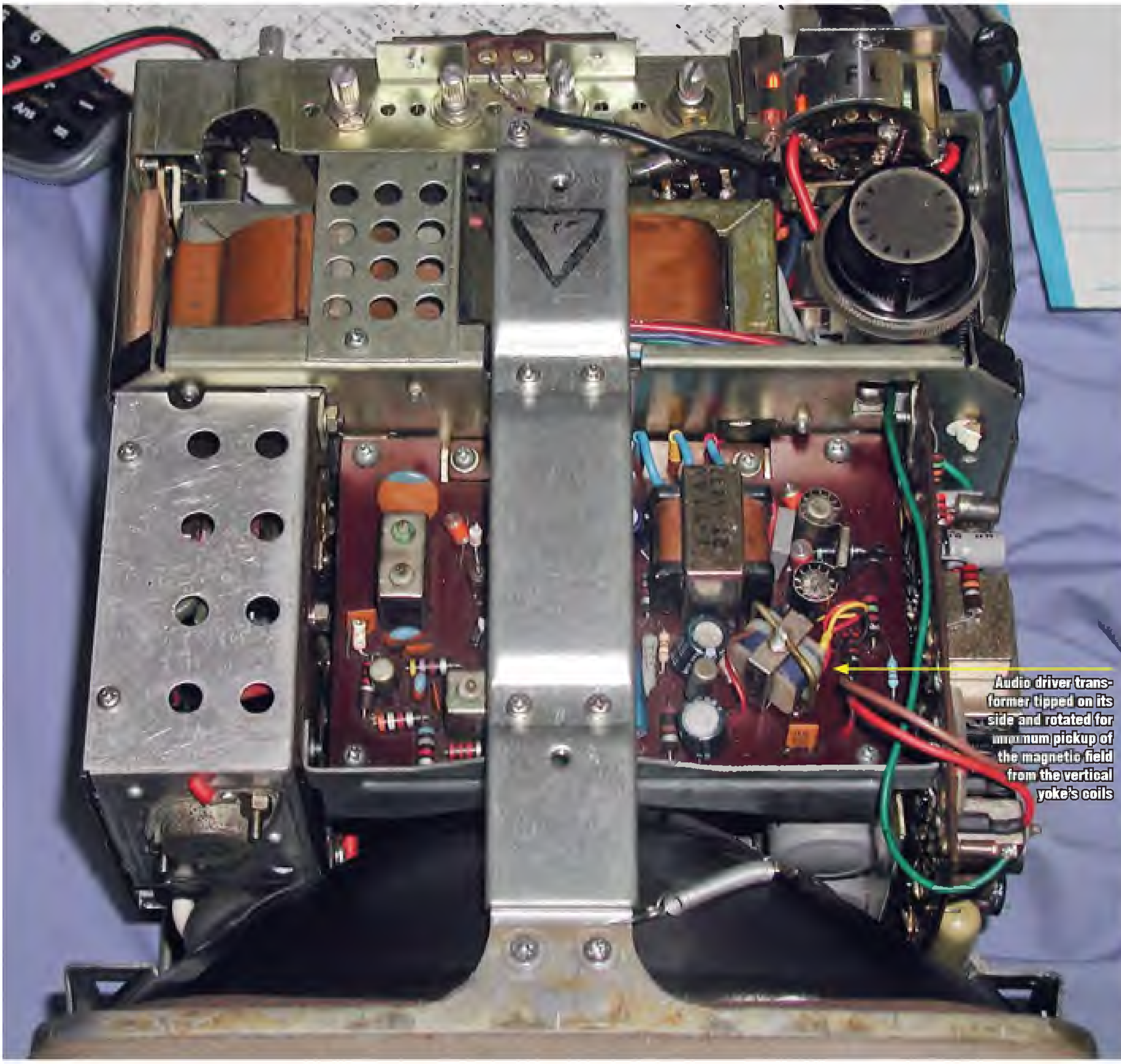
Later, I learned about the DG14TV diode, which was used in Australian-made AWA portable TV sets and also the AY102, either of which would have worked. It is likely that the DG14TV is merely a re-labelled 1N4785. Finally, from a wrecked Sanyo 8-P2 set a year or two later, I found one of the original gigantic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

I installed the 2N3731 in the set, recapped it (except for the large mains power supply filter capacitors), and that is when the fun began. After a while, the phenolic plate that supported the two valve EHT rectifiers became conductive, with arcing on its surface. 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 (see adjacent).

There appears to be a Mitsubishi logo on the line output transformer core in this set; Sanyo must have acquired it from them. It is the only place inside this set where such a logo is found.

The rubber-covered EHT cable, which I replaced in the 1970s, has now started to crack. So I replaced it again, this time with very high-quality white silicone-covered wire (see below). As a teenager, I did not have access to good wire like this.

Apart from the replacement EHT wire, the rest of the marked items were replaced during the original repair 45 years ago.



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

It was working on this TV set that I learned the art of sweeping the video and audio IFs with a sweep generator and scope. After aligning the set, I was generally pleased with its performance.

But there was an annoying vertical buzz in the audio caused (after much investigation) by the audio driver transformer core picking up radiated magnetic fields from the vertical yoke's coils. This was due to 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 (see above). I found that by tipping it on its side and rotating it to a particular 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 were abandoned in audio amplifiers, this sort of problem vanished too.

But, there was still something that troubled me: the horizontal scan linearity was stretched (expanded) at the beginning of scan (on the left) but 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 took me some years to understand the cause of this problem.

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, 7µF 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 powered it up again, after about a 40-year interval.

The set 'almost worked' on repowering it recently. One of the five or so 2000µF clamp-mounted electrolytic capacitors (which I had not originally replaced) promptly failed by heating and outgassing.

Interestingly, on a low-voltage test, the ESR, capacitance and leakage of all these old 25mm (one-inch) diameter capacitors read OK on my meters.

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

I therefore replaced all of the clamp-mounted capacitors in the set, and also the vertical yoke coil's coupling capacitor.

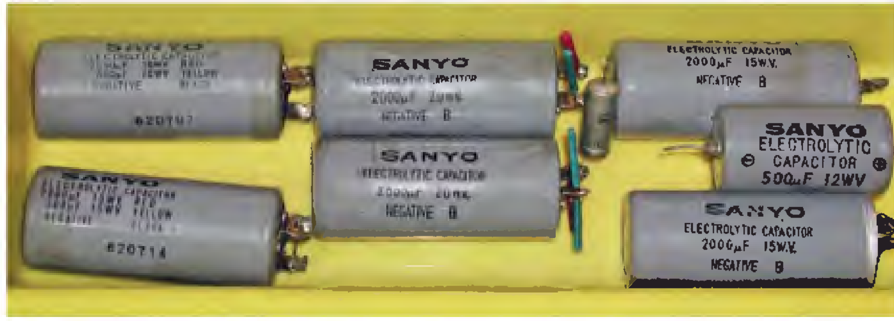
The original Sanyo capacitors are shown at upper right; they were fairly generous with the number they used. The set requires good power supply filtering as there is no electronic regulator for the 12V rail; merely a transformer and bridge rectifier when running from mains power. The larger 500µF axial electrolytic in the photo is the vertical yoke's coils coupling capacitor.

These capacitors are huge for their ratings compared to modern equivalents, which have about 20% the volume or less.

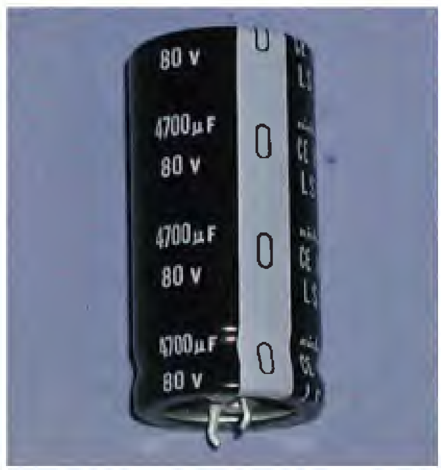
I had to remove the CRT from the set to replace the 500µF 12V-rated vertical yoke coupling cap. I replaced this one with a 125°C, 40V-rated 1000µF Rifa automotive-grade capacitor that will never likely need replacing. I replaced the 2000µF 15V units with 4700µF 80V Nichicon types. This was the closest I could find with a large enough diameter canister size to approximate the original appearance.

The extra capacity is not unhelpful when running from line power; it improved the noise rejection when running the TV from a 12V switchmode power supply too.

The replacement capacitors on the rear chassis are shown adjacent. This is the view into the battery compartment. This compartment once held, of

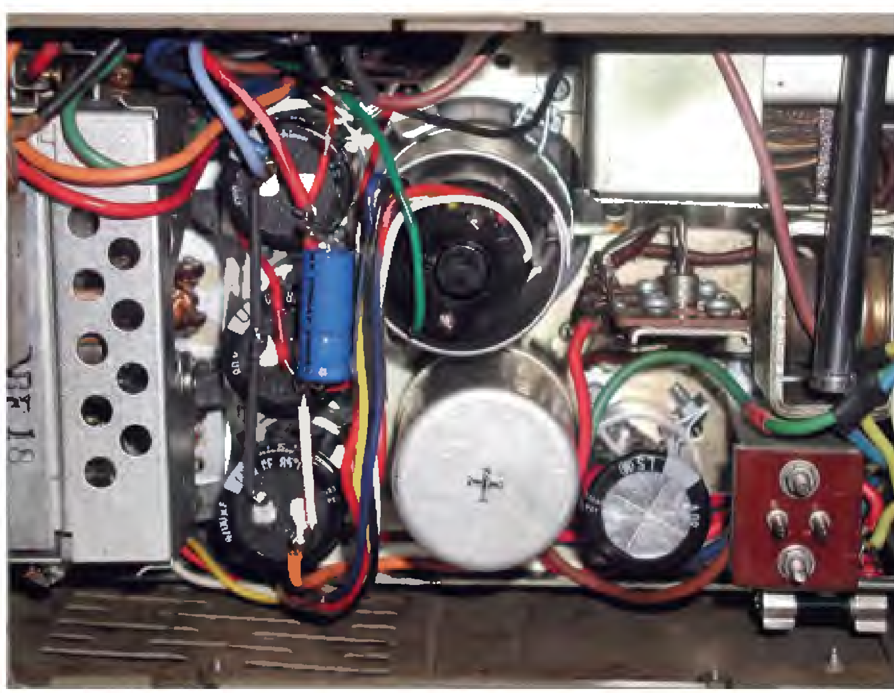


The original Sanyo capacitors (shown approximately half size) used for power supply filtering etc, had failed when the set was powered on. The 500µF capacitor at right is the coupling capacitor for the vertical yoke's coils. The rest of the 2000µF capacitors were replaced with 4700µF Nichicon types shown below (actual size), as they were the closest in terms of appearance and size.

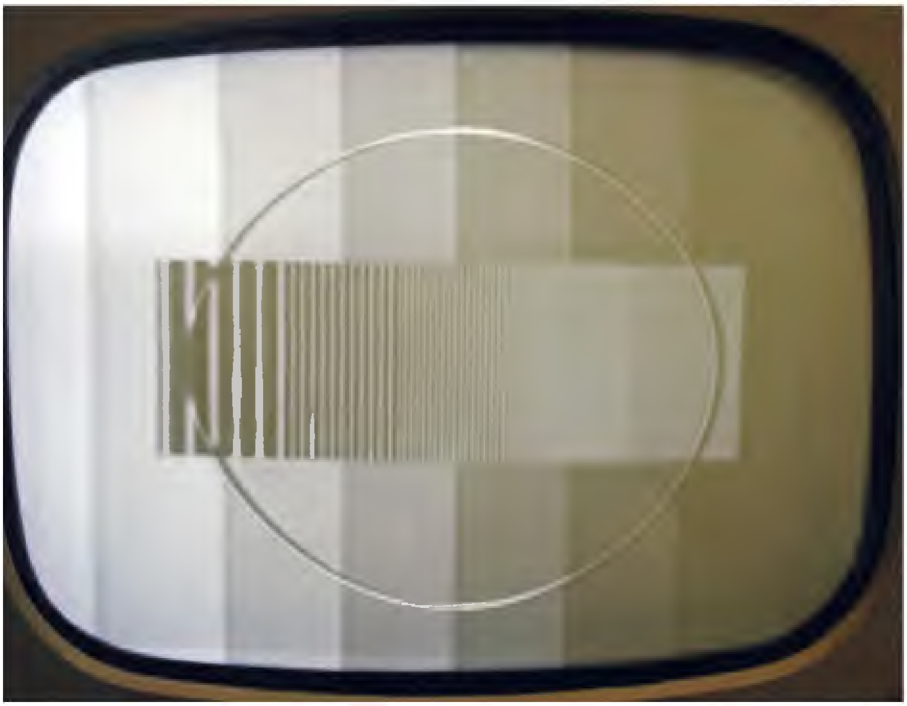


The Nichicon electrolytic capacitor, which has a diameter of approximately one inch (25mm).

The yoke coupling capacitor was replaced with this Rifa 1000µF automotive capacitor.



Four replacement Nichicon capacitors are shown installed here instead of the original 2000µF Sanyo ones. The original S-correction capacitor is also shown at the lower centre in a silver can marked with a cross.



The Sanyo 8-P2 TV being tested; the 3.8MHz bars are just visible (second set of lines from the right) which is OK given that the screen is eight inches diagonally.

all things, a 12V wet lead-acid battery, much like a small motorcycle battery.

The set is powered from this 12V battery, or by an external 230V AC mains supply. The manual states "when the voltage is below 10.5V, charge the battery immediately".

There is a selector switch on the top of the chassis. This switch has four modes which are viewed via a small clear window, which is illuminated by a neon bulb. The four modes are:

- **CH** – battery charged by mains voltage, said to take 10 hours.
- **DC** – powered from the internal 12V battery.
- **AC** – powered from 230V AC mains.
- **FL** – charge battery while playing the TV from mains power.

Performance and linearity

The high-frequency video performance of this set is reasonable. The display is shown above; when it is tuned in properly, the 3.8MHz bars are just visible, which is an adequate resolution for the 8-inch (20cm) diagonal screen.

Turning now to the horizontal linearity problem I mentioned earlier, compressed linearity is when the horizontal picture elements are cramped together along some part of a horizontal scan line.

This is due to a slower-moving electron beam, ie, 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 is when 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.

Note that in a TV or any other electronic apparatus which runs from a low-voltage supply, circuit currents must be higher at lower supply voltages 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 valve or transistor-based set. Therefore, an interesting design challenge crops up.

The peak yoke currents in a 12V-powered set need to be much higher than in a higher-voltage operated set for the same deflection power, yet the yoke winding ampere-turns must be similar.

This means that the yoke's winding wire (especially for the horizontal yoke coils) must be made of thick low-resistance wire, yet thin enough to physically wind into a formed yoke coil to get enough ampere-turns.

In 12V-operated sets, resistance in the horizontal yoke 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 realise exactly why this was the case.

In transistorised TVs, the horizontal scan output stage acts as a switch, and the rate of current increase is dependent on the inductance and resistance 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.

By contrast, the vertical scan stages act more-or-less like their audio amplifier counterparts, with the waveform

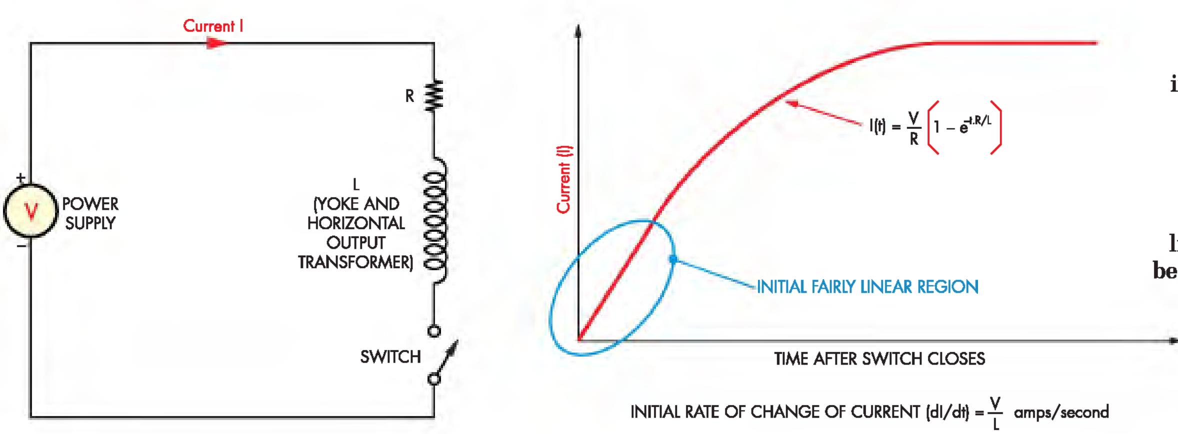


Fig.1: the change in current when a fixed DC voltage is applied across an RL circuit. The current will initially rise linearly with time before flattening off exponentially.

shape driving the output stages controlling the vertical scan linearity.

This horizontal scan linearity problem was primarily solved or ameliorated in the early solid-state TVs with horizontal yoke windings that were 'quadra-filar' wound. Sometimes, up to six strands of wire were paralleled to help keep the DC resistance of the horizontal yoke coils low, while still being able to wind and form them.

Later, the horizontal scan linearity in transistor TV sets and computer monitors was manipulated with a combination of 'S-correction' capacitors and magnetically saturable inductors (with a permanent magnet) in series with the horizontal yoke coils.

Close inspection though will show that most 12V-operated TVs of the very early 1960s have expanded scan linearity on the lefthand side, with no adjustment inside the TV set which can alter it. The technical explanation for this is as follows.

When a fixed DC voltage is applied across an RL circuit, the current initially rises linearly with time and flattens off in the usual inverted exponential manner (see Fig.1).

Initially at least, when a de-energised inductor is switched across a power supply, the rate of current increase is linear. It rises at V/L amps per second, where V is the power supply voltage and L the circuit inductance. Notice that this initial linear rate of current increase does not contain the variable R for resistance.

The yoke's coils and the power supply are not free from resistance, so as time passes, the rate of current increase flattens off and settles to a value of V/R amps. 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 near-linear part of the current ramp is used to scan the CRT's beam from the centre toward the right-hand side of the CRT's face.

On the righthand side of the scan (with no other corrections), compressed linearity is sometimes seen as the rate of current increase with time is tapering off.

However, a small amount of this righthand compression is helpful, as the sensitivity of the yoke (ie, the change in beam deflection for a change in yoke current) is greater for higher angles of beam deflection.

Therefore, the tapering rate of current increases with time towards the extreme righthand side of the scan, due to the L & R properties of the yoke, which tends to cancel this sensitivity effect. It is often not wholly cancelled, though; as explained below, S-correction capacitors are usually still required.

So it is fairly easy to achieve reasonable horizontal scan linearity in a 12V-operated transistor set, especially for small screen sizes and low range deflection angles, even without a magnetic linearity coil or S-correction capacitor, at least for the righthand half of the screen. That is, provided that the yoke's L and R values are suitable.

However, good linearity is much more difficult to achieve on the lefthand side of the scan.

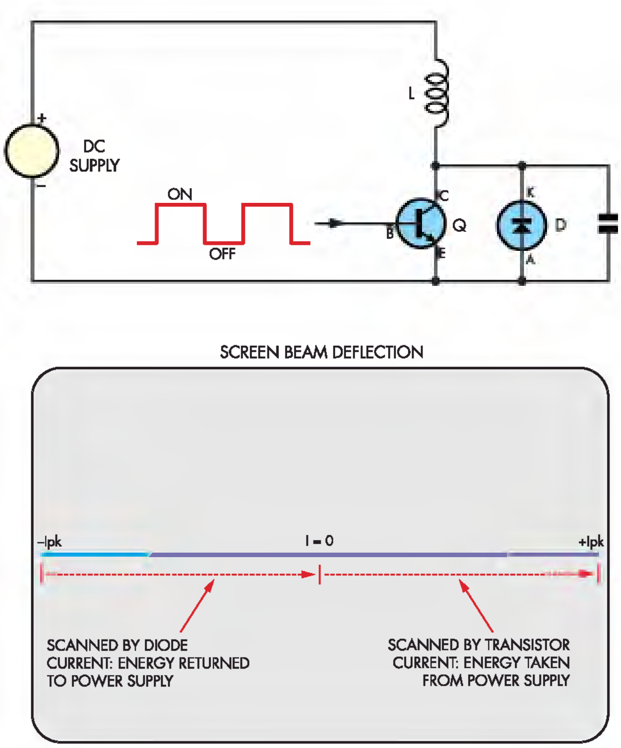
Horizontal deflection operation

Fig.2 shows a simplified horizontal deflection system with a switching transistor, damper diode, an inductance L (representing the horizontal yoke coils) and a tuning capacitor C, which tunes the flyback frequency.

The transistor's current ramps up as the CRT scans toward the righthand side of the raster. The damper diode carries the current during lefthand side scanning; 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. At the end of each horizontal scan line (after scanning the righthand side), the energy stored in the magnetic field of the yoke and the horizontal output transformer is transferred into the electric field of the tuning capacitor.

This is initiated by the switching transistor cutting off, and this energy transfer period is known as 'flyback'.



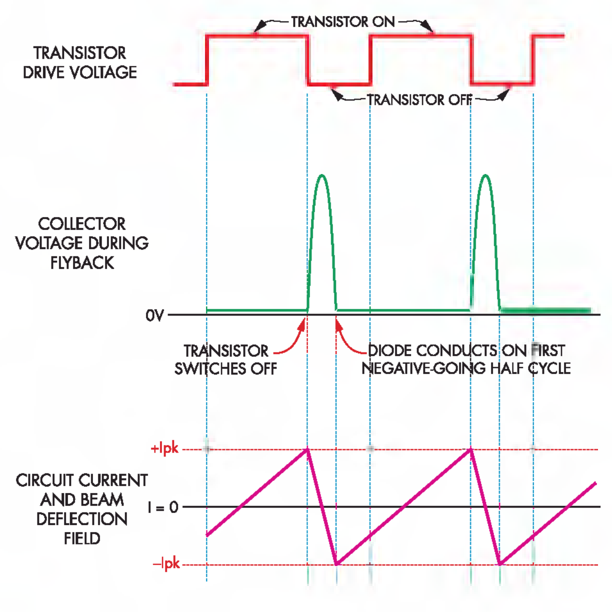
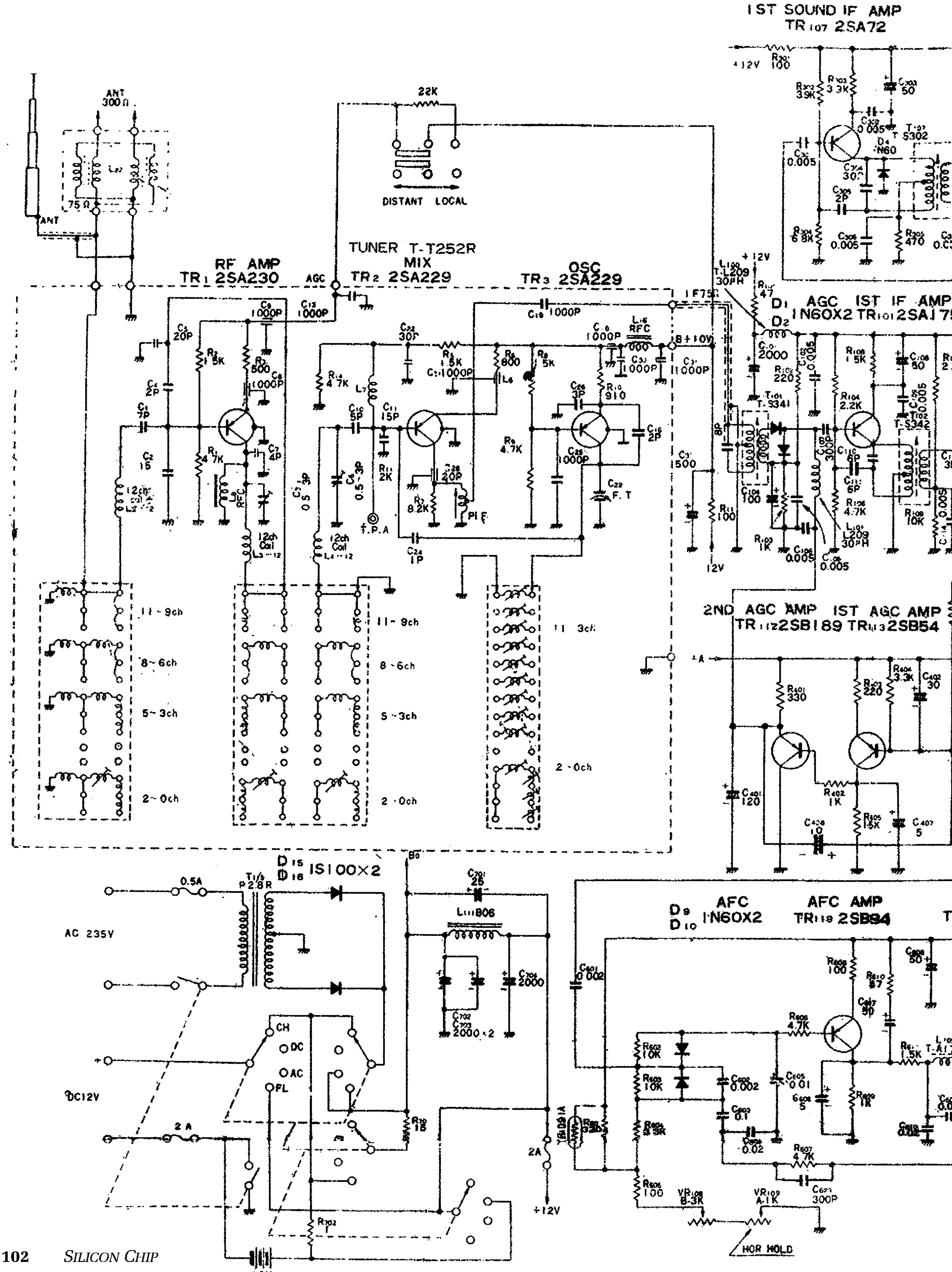


Fig.2: a simplified horizontal deflection system with a DC supply (V), switching transistor (Q), damper diode (D), an inductive load (L), and a tuning capacitor (C).



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TR107 2SA72
ANT 300Ω
75Ω
ANT
22K
DISTANT LOCAL
TUNER T-T252R
RF AMP
TR1 2SA230
AGC
MIX
TR2 2SA229
OSC
TR3 2SA229
D1 D2 AGC 1N60X2
1ST IF AMP
2ND AGC AMP
TR112 2SB189
1ST AGC AMP
TR113 2SB54
11~9ch
8~6ch
5~3ch
2~0ch
F.P.A
PIF
D15 D16 1S100X2
AC 235V
0.5A
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AFC
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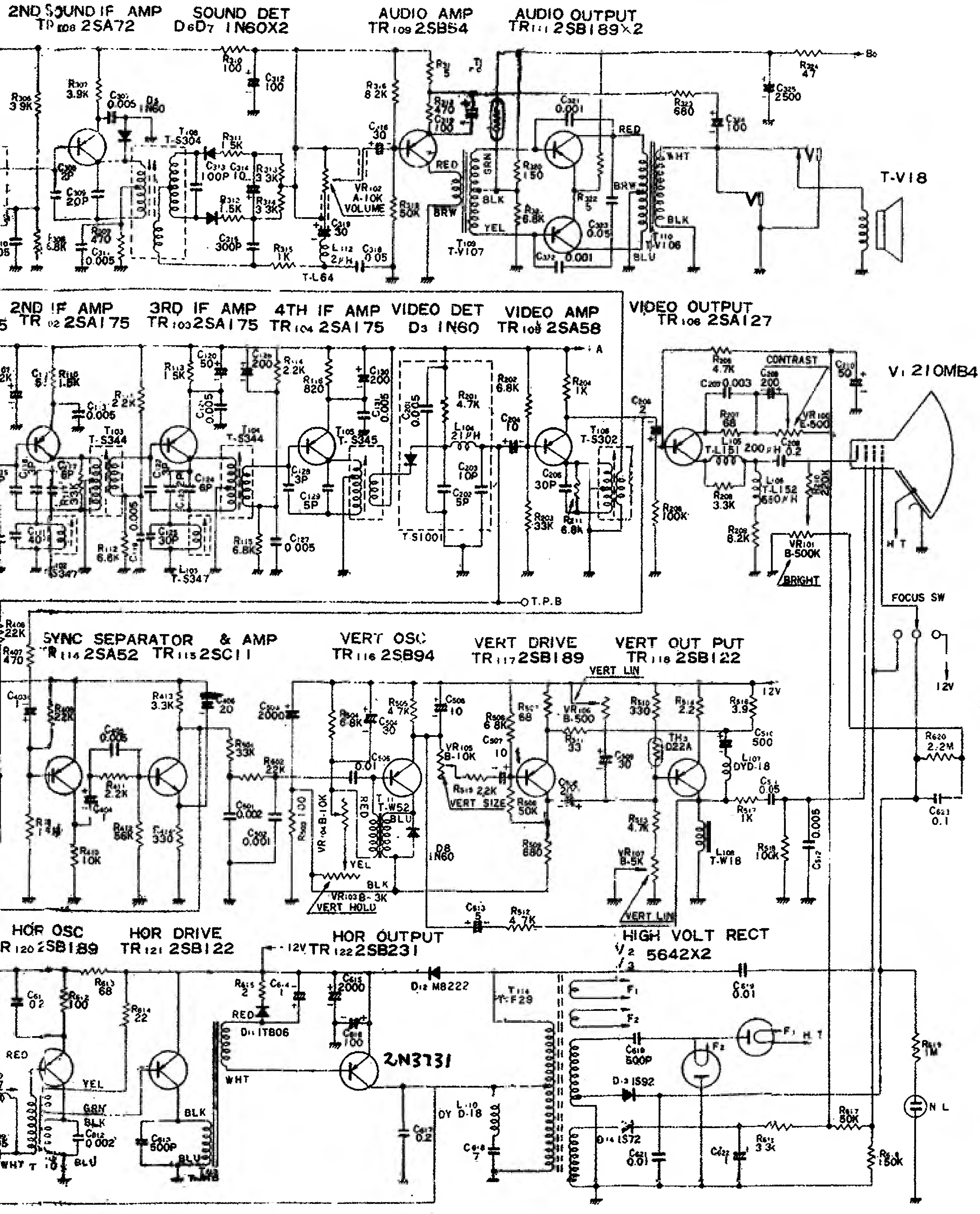


The circuit diagram for the Sanyo 8-P2. This was scanned from a photocopy and then cleaned up. The circuit and block diagram (shown overleaf) can also be downloaded from the Silicon Chip website: siliconchip.com.au/Shop/6/5788

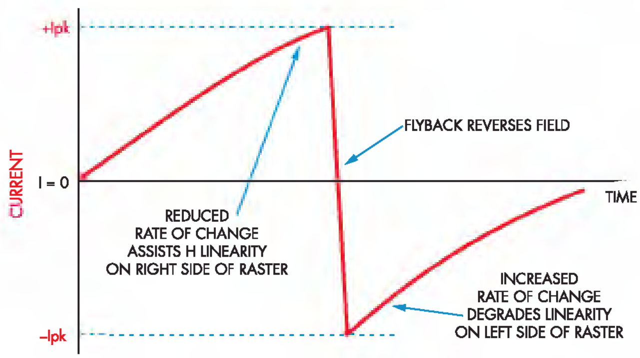


Fig.3 (left): how linearity correcting components affect the rate of change of current in the damper diode

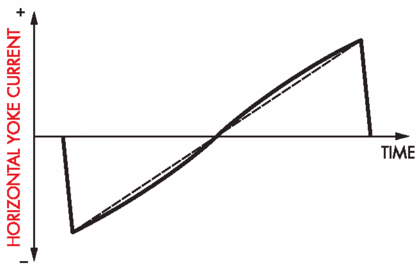


Fig.4: the red line shows how the S-correction capacitor alters the linear yoke current (black).

All the energy has moved into the capacitor's electric field halfway through the flyback period, when the voltage on the capacitor reaches a peak.

At this point, the yoke current is zero, and the beam is horizontally centred on the CRT. 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 12μs. The peak voltages can be in the range of 100V for a small monochrome TV and over 1kV in a large colour TV.

The end of the flyback period is just before the flyback diode conducts and after the capacitor's energy has been returned to the magnetic field. The capacitor's voltage is zero, and both the yoke current and the polarity of the magnetic field have reversed. The CRT's beam is at the lefthand side of the raster, ready to scan the next line.

The initial line scanning current after flyback on the lefthand side is achieved when the damper (or flyback/freewheeling) 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, on the lefthand side, the damper diode's current tapers off with time toward the scan centre. Its rate is initially high, rather than having a tapered or lower rate of change at the start of the scan on the lefthand side (which would mirror the shape of the current wave on the righthand side).

This effect aggravates, rather than cancels, the yoke's sensitivity for high deflection angles. The result is expanded linearity on the lefthand side of the CRT (see Fig.3). Therefore, without any linearity correcting components, the horizontal scan will always have expanded linearity on the left.

The horizontal linearity on my Sony Micro 5-303E TV is shown below. This set is an excellent case for studying horizontal scan linearity problems, because it is devoid of any linearity correcting components (it has neither an S-correction capacitor nor a magnetic linearity coil).

Its horizontal scan linearity properties show the intrinsic asymmetry of the linearity beautifully at the end of the line scan on either side. It also demonstrates the deflection sensitivity issue with the yoke, showing the central compression compared to the sides.

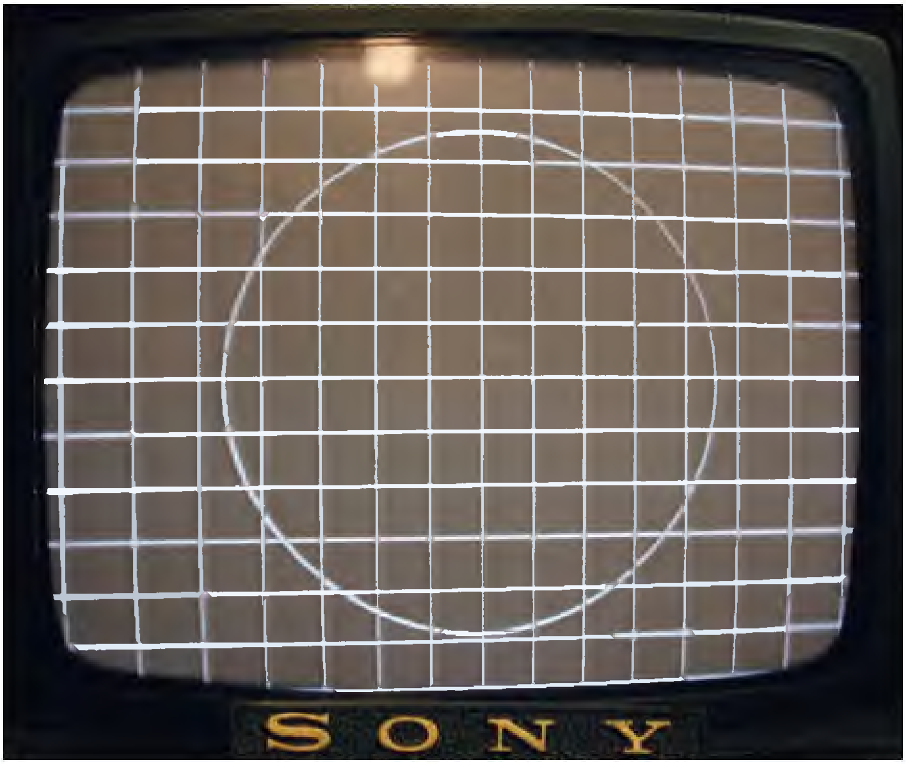
The traditional method which is used to correct the centre horizontal scan linearity, with respect to the sides, is the 'S-correction capacitor'. It is placed in series with the horizontal yoke coils. The Sanyo 8-P2 has this capacitor (even though the Sony Micro TV of the same year did not).

S-correction capacitors are used to effectively expand the linearity near the screen centre area and compress it toward the edges. This happens because the S-correction capacitor forms a resonant circuit with the inductance of the yoke coils to produce a partially sinusoidal current.

The red line in Fig.4 shows the effect of the S-correction capacitor. It alters the linear yoke current (the black line), which was closest to a linear sawtooth current beforehand.

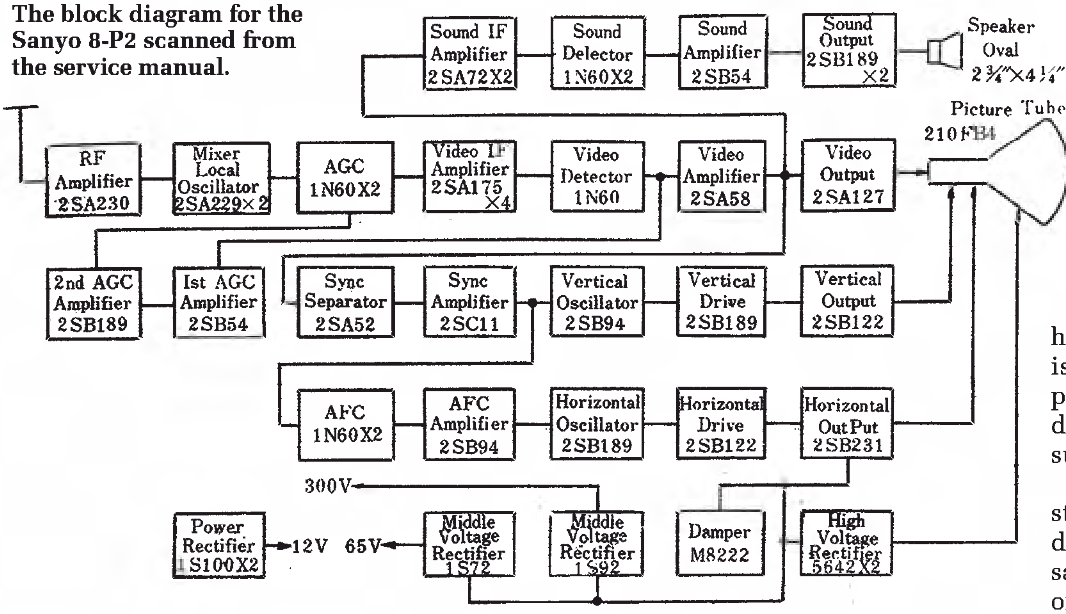
The S-correction capacitor increases the current rate of change with time near the centre of the scan, expanding the linearity there and compressing it at either side.

An advantage of an S-correction (or



The horizontal linearity test performed on a Sony Micro 5-303E TV, this acts as a reference to a set without any linearity correcting components.

The block diagram for the Sanyo 8-P2 scanned from the service manual.



another coupling capacitor) in series with the yoke's coils is that it isolates any DC voltage present. This means that the return point of the yoke connections can either be to the 12V supply or ground.

The linearity of the image on the Sanyo 8-P2 is shown below, which has an S-correction capacitor. Unlike the Sony Micro TV, the horizontal linearity of the central area of the screen (B) is very similar to that near the righthand side (C), thanks to S-correction.

But it is still expanded in the region A on the lefthand side, due to the magnetic field reversal and the current waveform shape.

As explained earlier, this is because the shape of the current waveform after flyback aggravates the linearity problem, rather than helping it. But there is another factor related to the circuit resistances.

It was noted before that any resistance in the yoke degrades the horizontal linearity.

When the righthand 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 lefthand side is scanned by the current passing through the damper diode back to the power supply.

In many horizontal output stage designs, the damper diode is not connected to the same point as the collector of the output transistor, as shown in Fig.2.

A small tap, a few turns away on the output transformer, helps to bring the damper diode into conduction a little earlier and ensures 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 TVs running from lower power supply voltages and the high peak horizontal yoke coil currents associated with that, horizontal scan linearity in early 1960s vintage TV's was always a problem.

It 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. These allowed asymmetric 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.

In the case of the Sony Micro 5-303E 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 righthand side of the scan, it would have made the linearity defect on the lefthand side more obvious.

As it stands with that set, the horizontal scan errors overall look better averaged out. SC

The horizontal linearity of the Sanyo 8-P2 is not as good as the adjacent Sony TV (for example region "A") despite it having an S-correction capacitor.