RESTORING THE SONY MICRO-TV MODEL 5-303E.

H. Holden. May 2020.

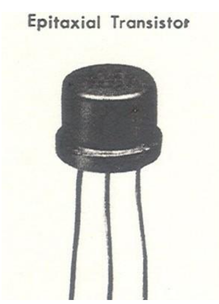
The photo above is of the TV I restored. The photo below is a page from Life Magazine, March 1963, showing this amazing little TV set:

I didn’t realize at that time that this was very clever marketing, to show the Micro-TV next to two very young children possibly only 3 to 4 years old or thereabouts. It gives a size ratio to the image and to the TV itself, without having to put a geometric object of a known size, or a ruler, into the frame to show just how tiny this TV was. Also showing a real life application a parent might benefit from; the entertainment of young children. Just sometimes the advertising agencies actually do a really great job. In more recent times, the field of advertising has been cynically renamed “perception management”.

SONY’S MIRACLE MICRO-TV:

The Sony Micro-TV was revolutionary. It set the stage for what the Japanese Electronic Engineers do very well; miniaturize things. The 5-303 was great achievement in 1962. It was not Sony’s first miniature TV though. In America the small Philco Safari TV beat Sony’s first small transistor TV, the TV8-301, to market in the same year, 1959.

The Sony Micro-TV sported a new generation of Silicon Power Transistors that had temperature specifications and stability unheard of in Germanium transistors that preceded them. Sony developed these transistors especially for use in their own TV sets. The one that was proclaimed to be the mover and shaker was the 2SC140.



Brief Specifications of the SONY Epitaxial Transistor 2SC140

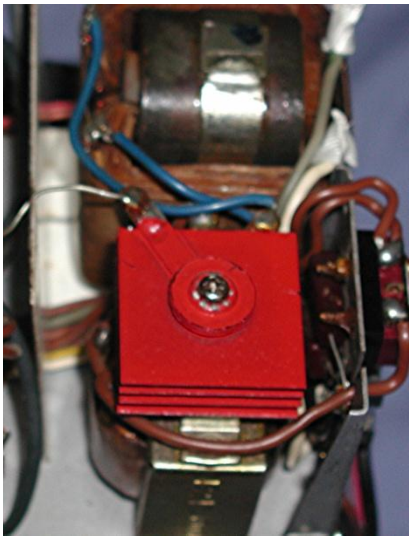
Maximum Collector-Base Voltage :	60 V
Maximum Collector Current :	1A
Collector Dissipation (Max) :	1.7 W (without heat sink)
Collector Saturation Resistance (Rs) :	2Ω
Maximum Junction Temperature :	175°C

Clearly, Sony was very proud of this transistor and they wanted to show off its spectacular features.

The 2SC140 transistor was used in the vertical output stage and the horizontal oscillator and horizontal driver. (Oddly with a 2SD65 NPN Germanium transistor buffer stage in between them, part of the subject of this article)

Other silicon transistors were the 2SC15 used as the video output device and a 2SC41 used as the Horizontal output transistor, Generally, the rest of the transistors in the set are Germanium PNP types, including those in the Tuner, IF stages and the split driver transformer style Audio Amplifier. There are also 2SC73 NPN Germanium types used.

Other interesting features include a somewhat retro unregulated 12V DC power supply based on a Selenium bridge rectifier.



140CB4 CRT

The EHT rectifiers were small tube diodes,a commercial type, the 1DK1, wired as a voltage multiplier to acquire 8kV for the screen. Due to the fact the EHT voltage is very high for the screen size (just under 140cm diagonal) the set can produce amazing high contrast images even in high level room lighting, quoted at 500 Lux by Sony. The CRT was a 5 inch 70 degree deflection type especially designed by Sony.

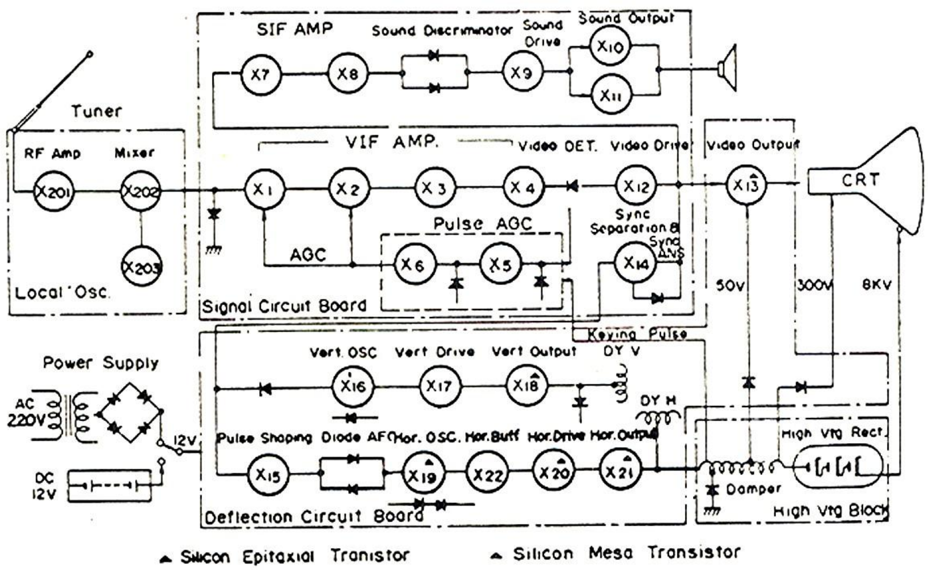
The CRT specs:

Specifications of Picture Tube 140CB4

Type :	Rectangular Frame	Diagonal Dimension :	137 mm (5-3/8″)
Neck Diameter :	20 mm (3/4″)	Full Length :	161mm (6-5/16″)
Deflection :	Electromagnetic	Focusing :	Electrostatic Automatic
Deflection Angle :	70-degree	Ion Trap :	Unnecessary
Heater Voltage :	12.0V, 70 mA	Anode Voltage :	8 KV
Anode Current :	50μA	2nd Grid Voltage :	300 V
Focusing Voltage	0～120 V	1st Grid Cut-off Voltage	Approx.—25 V
Resolution:	Horizontal: 28 lines/cm or 300 lines full picture		
	Vertical: 45 lines/cm or 400 lines full picture.		

SYSTEM BLOCK DIAGRAM:

Block Diagram



It was customary in the manual of the times to include a block diagram. The block diagram provides a helpful overview before consulting the schematic. Sony indicated where the diodes were as well as the transistors. Also the label on the rear of the TV says how many diodes & transistors the TV contained. Since these were expensive items, perceived value was in the number of semiconductors inside, 25 transistors and 20 diodes (5 of the transistors were Silicon types).

For example at the time, a transistor radio of the era might boast “7 transistors” and perceived by the consumer to be better than a “6 transistor radio”. These days there would be no attempt at such a notion for a marketing tool, as single IC might contain many thousands of transistor junctions and the idea would be ludicrous.

The Micro –TV was amazingly sensitive, Sony quoted a maximum sensitivity of 10uV at the input for 10V at the picture tube cathode. The set also had a gated AGC system advanced for the time. The power consumption was quoted at 13W on AC operation and 9.6W on DC operation. The set was either Line powered or 12V battery operated. The set weighed in at 8 lbs. I read on a website that this sets “runs hot” which is nonsense. 13W for the size of the set, it barely warms up and there is plenty of convection cooling.

Sony set their own criteria for this TV, the targets were:

1) To be small in size & low weight.

2) To have the lowest power consumption of any mass produced TV.

3) To operate perfectly as a completely portable TV set under all conditions.

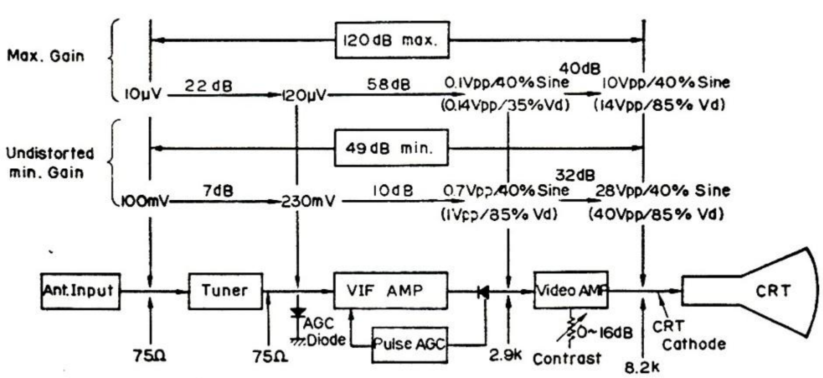
4) To provide facilities for easy servicing.

That last objective has now all but completely disappeared from the electronics industry. Many items now are designed for rapid and expedient assembly at a factory. Disassembly and repair is another matter, if it can even be done without special tools etc. Items are “life cycled” and the expectation that a customer would have any items repaired has faded away, into a new age model of replacement goods.

Sony claimed that the AGC system (with its pulse or gated design and the automatic noise suppression they dubbed ANS) that the Micro-TV would maintain synchronization in a moving car where the signal strength varies suddenly and almost continuously and in the presence of strong engine noise radiation.

Sony also published a very unusual and helpful signal level summary that is seldom seen on other manufacturer’s TV service manuals:

Level Diagram for Video

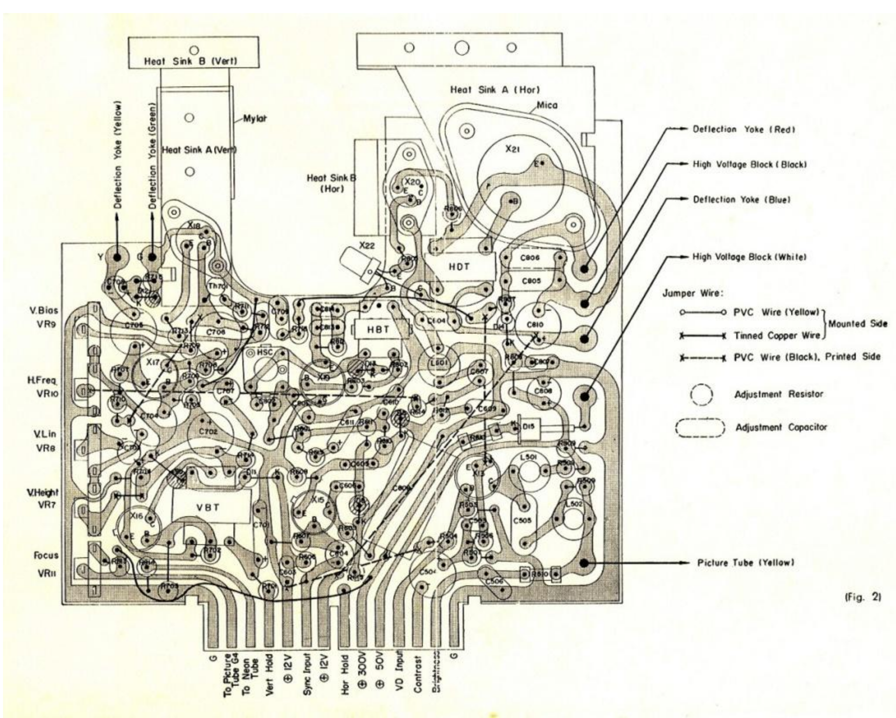


(Fig. 8)

As indicated, the maximum signal gain is an astonishing 120dB. In practice I have found that for a stable visible picture and sync it requires about 100uV input at the set’s 75R input connector and by about 150uV to 200uV it is driven just out of the snow and a super clean video image results.

The PCB's:

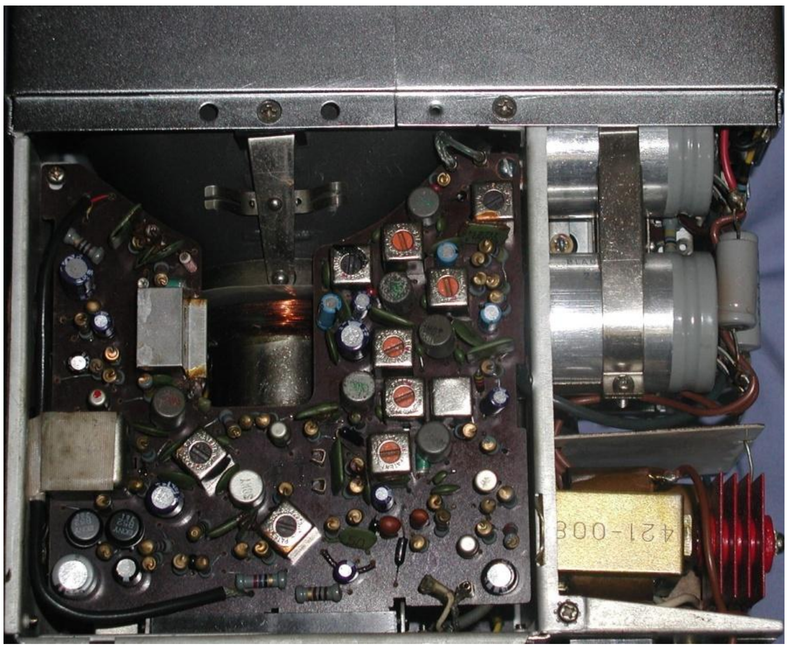
Cleverly, to help servicing, Sony broke the set into two pcb's, one above near the top of the chassis and one below. Both of these pcb's had a similar geometry and a cut out near the front near the CRT bulb area and a pcb connector at the rear. Looking at the upper (top board) first, it contained the AFC (automatic frequency control for the horizontal hold system), the Horizontal and Vertical scan oscillators and the Horizontal and Vertical scan power output stages. On account of this, Sony created aluminium flanges that extended from the pcb area, to the front metal escutcheon of the set, to drag heat away from the power output devices. A photo of this board from my set is shown below:

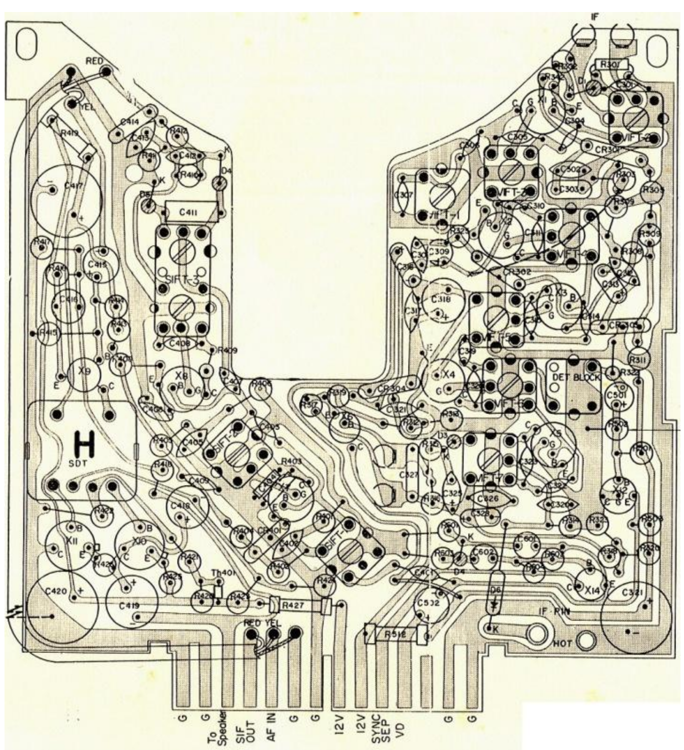


(Fig. 2)

Sony also provided diagrams of the pcb tracks. Oddly, they are as if looking through the component side of the pcb. When working on the set, it is better to scan these into a computer and flip them over, so the tracks seen on the diagram match the tracks that you see on the pcb surface. This is especially the case for the upper pcb, where the board is mounted with the tracks facing outward and upward and the components out of view.

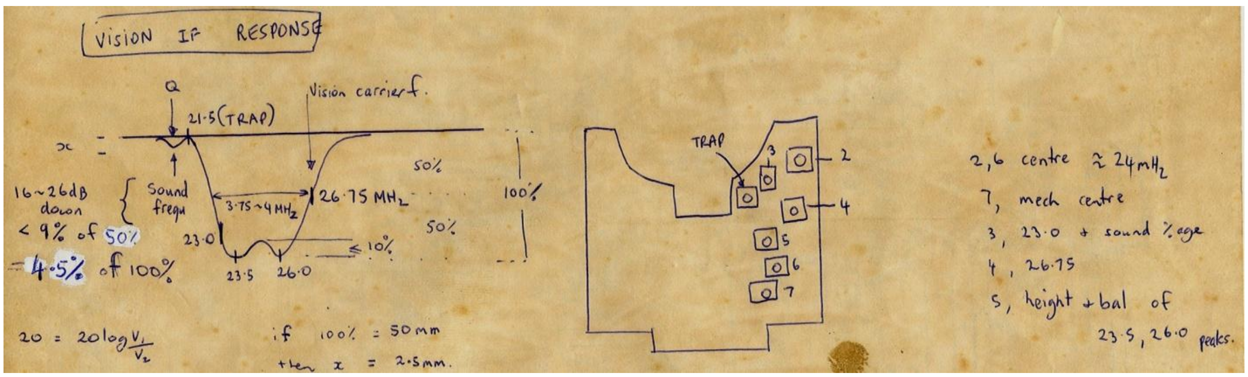
The signal board is equally as impressive for the time:



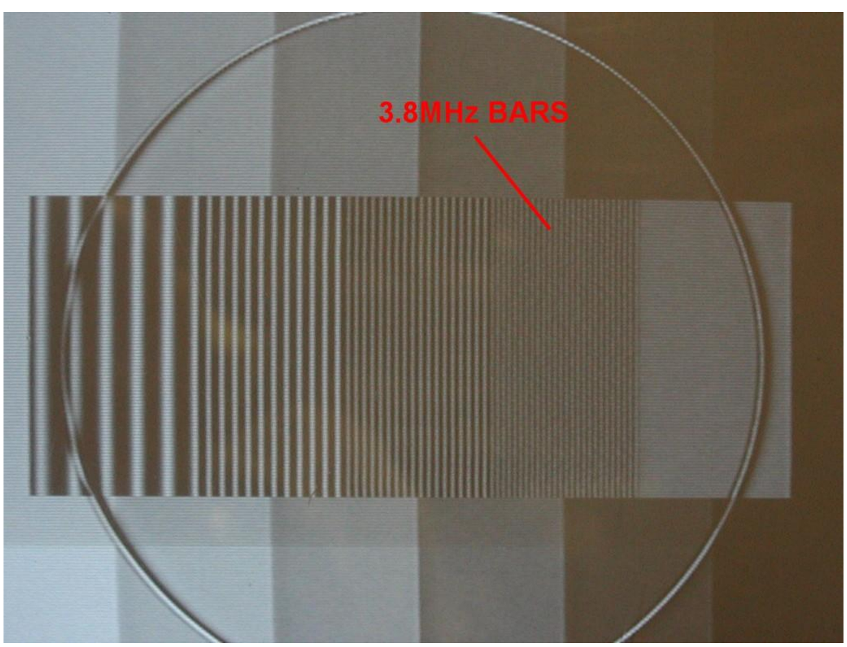


RESTORING MY MICRO-TV:

Back in the late 1970's or early 1980's when I bought this TV, it was defective. Even then nearly all the small electrolytic capacitors had failed. Except the Alox ones (see below).The large main power supply capacitors were ok (and interestingly they still are). I recapped the set and did a full RF alignment with a sweep generator & scope. I found some of my original hand written notes from that time, where I kept a record of the video IF response curve and how the particular IF adjustments affected it. I also kept notes on the sound IF alignment. One important thing is that the sound response and adjustments are such that they are ideal when the tuning is such that the high frequency detail in the video image is optimal.



The bandwidth of the IF was set at 3.75MHz (as per Sony specs). With it done this way I found that the 3.8MHz bars from my pattern generator were easily resolved. The 4.8MHz bars are not visible, as expected:

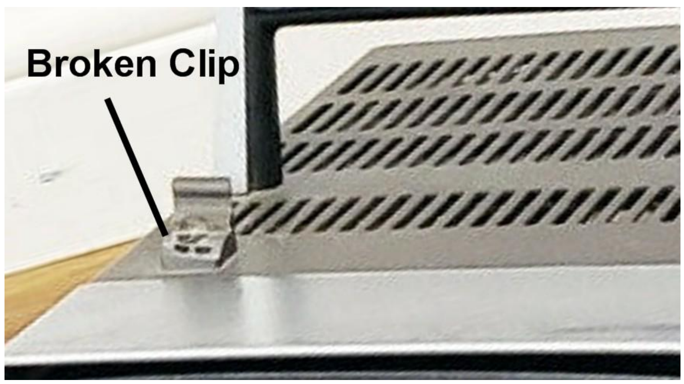


The above is the sort of performance you can expect to get with the video IF correctly set up with a sweep generator and oscilloscope. Latter day TV restorers often try to get the video IF set up by other methods, but I'm afraid there are no shortcuts here and for excellent results there is no escaping the need for the sweep generator & scope.

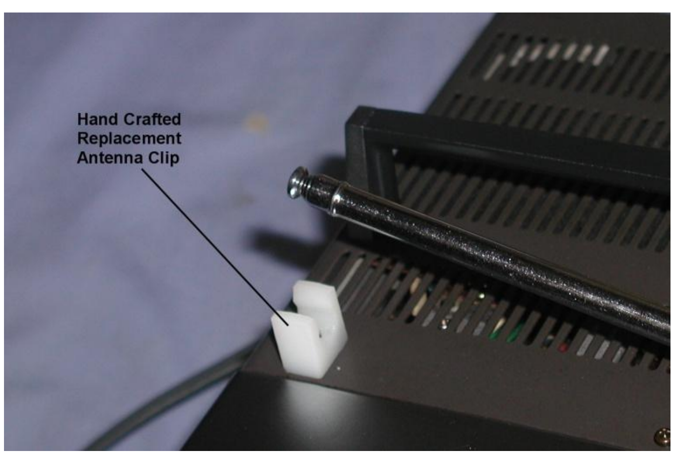
Also, of note, my TV has a VHF tuner, but the Sony Micro-TV was also released with a UHF tuner. These were popular in North America.

Mechanical Issues:

Fortunately the set I acquired had few mechanical issues. One known weak point with these sets is the antenna clip. The plastic hardens and cracks with time:



I simply hand crafted a new one from a block of Nylon:



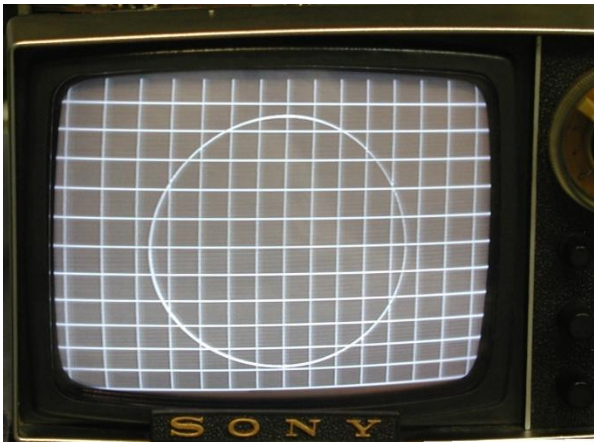
This little TV sat in its box for about 40 years after I initially recapped it. I only occasionally used it. Recently I pulled it out again. Despite just being in storage it had developed some faults. One fault in particular was intermittent and very difficult to solve, it took a few days and a lot of patience to get to the bottom of it.

1) The vertical deflection linearity was poor at the bottom of the scanning raster, not correctable with the height and linearity controls. (This is often a symptom of high ESR electrolytic capacitors in the vertical output stage area, but not in this case).

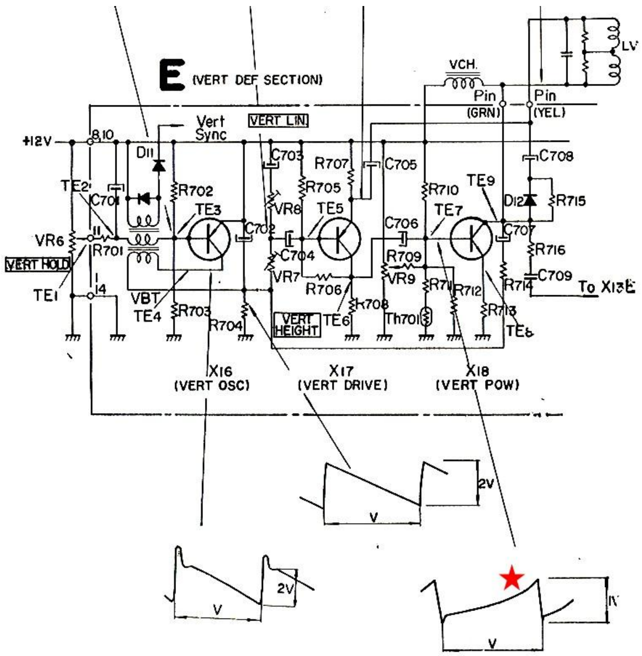
2) The Horizontal Hold was intermittent, with a combination of small left and right jittery movement of the horizontal position of the image, intermittently disappearing for some hours, then returning. But also the occasional massive horizontal movement with total loss of horizontal hold at times with a sudden loss of raster width and the H oscillator abruptly running a much higher frequency than it should at around 20kHz.

Dealing with the faults:

In the case of the vertical linearity issue, I checked the power supply, the resistors & electrolytic capacitors in the vertical stages, none were out of spec or defective, including the vertical yoke coil's coupling capacitor. A photo below shows the V linearity issue (The Horizontal linearity is also not ideal, this is discussed later as it is intrinsic to the design and not easy to adjust).



As can be seen, the raster lines are compressed toward the bottom. In this set there is plenty of height control and the raster will easily double in height and there is plenty of dynamic range in the output stage. The V Linearity control though only has a significant effect at the top of the raster. One might think that to acquire a linear vertical scan, that the current in the vertical output transistor, during scan time at least, should be a linear ramp. On testing with the scope, with the raster shown above, the transistor's current appeared as a near perfect linear ramp, but this is not normal.



However, to get a linear scan in reality the properties of the vertical yoke coils, the yoke coupling capacitor and the collector load choke need to be compensated for. So in fact the current and transistor base drive voltage that is required, for a linear raster scan, needs to flare upwards toward the end of the scan. This is shown with the required waveform (red star nearby in the diagram above) in Sony's manual.

Sony achieved the upward curved waveform by placing *positive* feedback around the vertical output stage with the two components, C707, a 10uF electrolytic capacitor and R714 a 620R resistor. This feedback is not enough to cause the amplifier to oscillate, but resulted in the upward rise of current in an exponential like manner toward the end of scan time. The positive feedback also helped with a fast flyback.

Yet in my set, with normal resistors and capacitors and tested transistors, throughout this deflection system, the output stage current was more of a linear ramp and the raster compressed at the bottom.

Also, the sawtooth voltage developed across a normal and tested 100uF capacitor C702, by the 330 Ohm charging resistor R704 was closer to 4V peak to peak, rather than the 2Vpp specified in the service manual. One aggravating factor here is the 20mSec interval with a 50Hz vertical scan frequency, versus the 0.0167mS rate of the 60Hz scan frequency used in the USA. The voltages here also agreed perfectly with calculations.

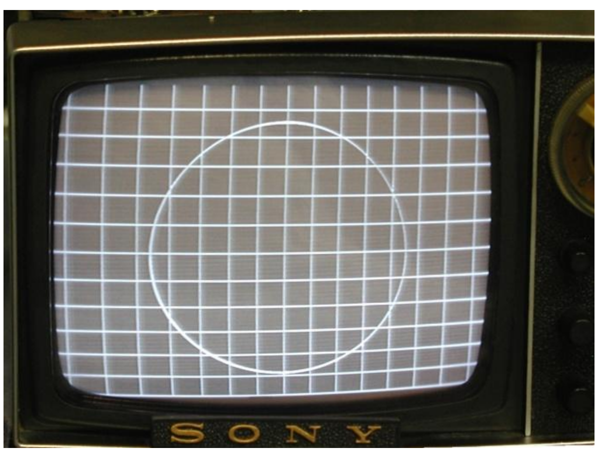
This means that in the 50Hz system at least the height control requires to be set at near minimum (larger resistance) this reduces the value of the positive feedback signal that is mixed in with the sawtooth voltage (as it has to pass via the height control) to the vertical amplifier's input at transistor X17's base. This aggravates the compression of scan lines toward the end of the scan at the bottom of the raster.

The repair to correct the poor scan linearity was achieved by increasing the value of R704, from 330 Ohms to 750 Ohms. This reduced the amplitude of the sawtooth voltage across R704 to 2.4V pp, close to the manual's suggestion of 2Vpp. (Also the most negative part of the sawtooth waveform, with these values sits at 6.6V for future reference).

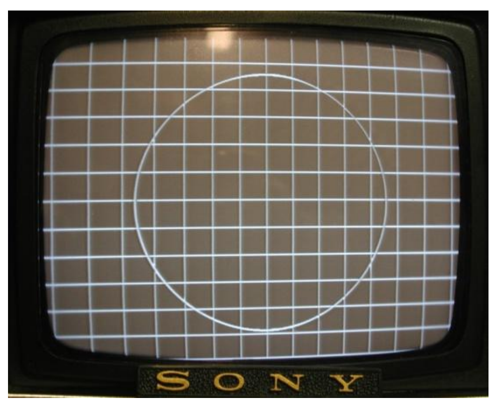
This meant that the height control could be adjusted for a lower resistance (more height). This improved the positive feedback. To further improve things I altered the value of C707 from 10uF to 15uF increasing the positive feedback.

Another helpful change was to parallel a 3 Ohm resistor, with the existing 3 ohm resistor in the emitter of the vertical output transistor. Normally there, the voltage across the existing resistor is 0.33V, making an emitter current of 110mA. With the additional resistor added the voltage drops to 0.22V across 1.5 ohms, and the new emitter current is 146mA, an additional current of about 36mA and an additional power dissipation of 0.43W, taking the transistor's power dissipation from about 1.32W to 1.75W.

For the 2SC140 transistor, as Sony advised, it is capable of 1.75W *without* a heat sink, and in this case it has a heat sink and only runs warm to touch. Probably, there are some aging effects on this transistor over time. I do not want to replace it because of its historical significance. The result, of the before and after the Vertical linearity corrections are shown below:

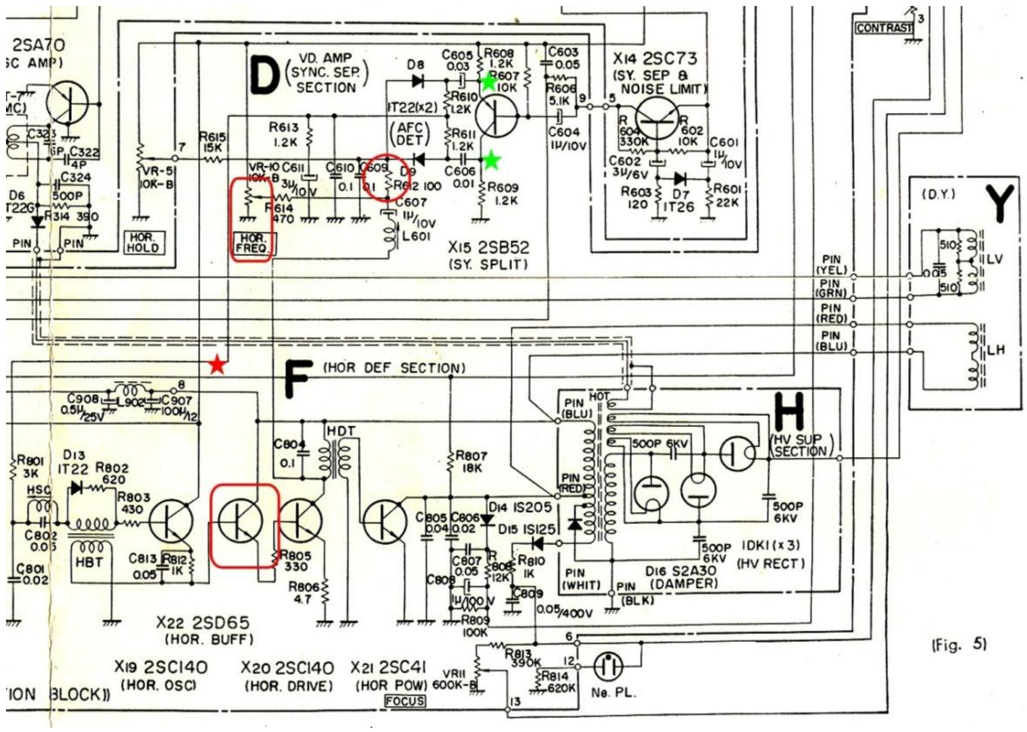


BEFORE

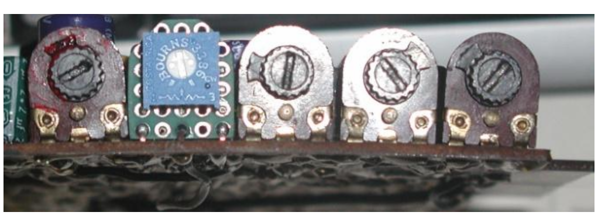


AFTER

Once the vertical scan linearity issue was solved, I moved onto to the Horizontal image instability and hold issues. To solve this problem was tricker than usual. There were three problems. The circuit, with some boxes and stars to help explain it:



Firstly, on the simple side of things, the H.Hold preset was defective and at a certain point of its rotation, the resistance value suddenly altered (not corrected by cleaning). If it was set near that position, the resistance value was erratic. So this was replaced by mounting a modern 10k preset pot on a small piece of plated through hole spot board so as to mount it correctly:

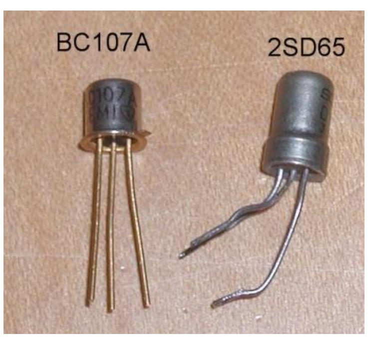


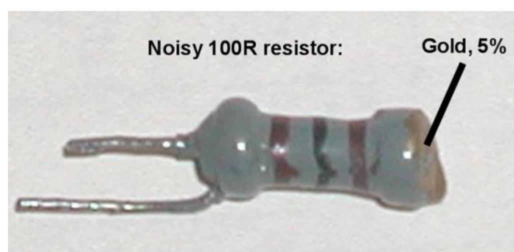
Notice that the resistors are radial type to stand up off the pcb, most are 5% tolerance parts, all but one of these resistors in my set were in excellent condition.

Secondly, the cause of the sudden massive change in horizontal frequency was very interesting. The Germanium NPN buffer transistor X22, a 2SD65 was intermittent, it suddenly loses its ability to buffer and the sudden loading on the H oscillator forced the scan frequency up very high to around 20kHz, well outside the capture range of the AFC.

I concluded that one of two things was happening to this transistor, either the collector connection inside the transistor was intermittently going open circuit, or the base to emitter terminals inside the transistor were being intermittently shorted out by a Tin Whisker for example. Both mechanisms result in the same failure to buffer. Of the two, I'm very suspicious that it is tin whisker disease, because I could not detect any voltage drop at all across the B-E connections at the time of the failure and one would have expected about 300mV.

A suitable NPN Germanium transistor replacement for the 2SD65 is an AC127. In this case though, since it is a switching circuit, not an analog circuit with specific bias requirements and the transistors around it are Silicon types, I simply replaced it with a high quality gold plated leg vintage BC107A. Normally though in signal process circuits I would replace a Germanium with an equivalent Germanium type, to avoid any other changes in the biasing.





Thirdly, and this is where the fun really began to solve the final problem, it took about 3 days on and off, because it was an intermittent & fault to locate.

After fixing the first two issues I was initially convinced all was well. Then much to my horror, an intermittent fault remained. The horizontal position of the locked image had a random jitter, a few mm this way and that. Then the problem would disappear for some hours and return.

One issue is with the horizontal AFC in lock, any changes inside the control loop, from an intermittent component, will tend to partially cancel due to the loop behaviour.

So initially a number of thoughts crossed my mind; could the incoming sync pulses be changing their shape randomly? Could the phase splitter transistor driving the AFC diodes be noisy? Could an AFC diode be noisy or could the old Alox capacitors be defective (not see below) or maybe the H oscillator transistor was defective and noisy and having erratic small frequency offsets to cause the effect.

Where was the fault in this loop?

I decided the better move was to break the loop (red star in the diagram) I fed a clean DC control voltage via R801(3k) to the H oscillator and watched the test pattern float by horizontally. The oscillator appeared very stable, certainly with no jitter in the frequency, so at least that part of the circuit was ruled out.

Looking at the AFC voltage on the scope, with the broken loop, the fault was present. The DC level of the AFC voltage was randomly jumping up and down about 50 to 100mV at times.

I also tried feeding clean syncs from the generator directly into the phase splitter X15, the fault remained. At that point I disconnected the two coupling capacitors on one of their legs on the output of the phase splitter (green stars on the diagram) using solder wick and a temp controlled soldering iron (helps to avoid any pcb damage, these old phenolic pcb's are very heat sensitive) The fault remained, so that ruled out the phase splitter transistor & its resistors and the two disconnected capacitors.

At this point I thought the most likely explanation was that one of the AFC diodes was defective and probably noisy. They are IT22 germanium types. I replaced them one at a time with OA47 diodes. The fault and the jitter on the AFC output still remained.

At this point I double checked all of the capacitors. I had previously replaced the Alox capacitors C611 and C607 with high quality Wima non electrolytic types. I eliminated all the other capacitors by de-soldering one leg and by substitution. The intermittent fault still remained.

At this point I was running out of ideas, so I started checking the resistors. I was worried if I heated them, the fault might vanish. Rather than unsoldering any, looking at the circuit, I could see no reason why I couldn't eliminate each one in a test by shorting it out. The resistors to test for noise were R610, R611 R614, R615 and R612. All of these resistors had globally correct values on the meter. When I shorted out the 100R resistor R612 the voltage jitter vanished. The intermittent fault causing the small, yet obvious Horizontal picture shift was this resistor. Inspection of the resistor showed it to look physically normal, but on testing and passing a current, its resistance value was erratic.

Horizontal Linearity:

Also noted from the screen photos, the H linearity is a little stretched on the left, compared to the R. In more modern video monitors & TV's, two things are done to correct H linearity errors. One is to have an S correction capacitor in series with the H yoke coils and the other is to have an adjustable magnetically saturable reactor coil on series too. Without those (this set has neither of these nor a width control inductor either) the linearity errors seen result from the lower dynamic impedance of a saturated transistor scanning the right side of the raster, versus the higher dynamic impedance of the damper diode scanning the left side of the raster.

To correct these H scan linearity errors, would require more H scan width, meaning an increased HT with the same LOPT and Yoke and the addition of a width control inductor, an S correction capacitor and magnetic saturable reactor. So it is not really a practical proposition to modify it. In this case better to accept those errors as a feature of the more simple design.

General remarks about the raster scanning in the Micro-TV:

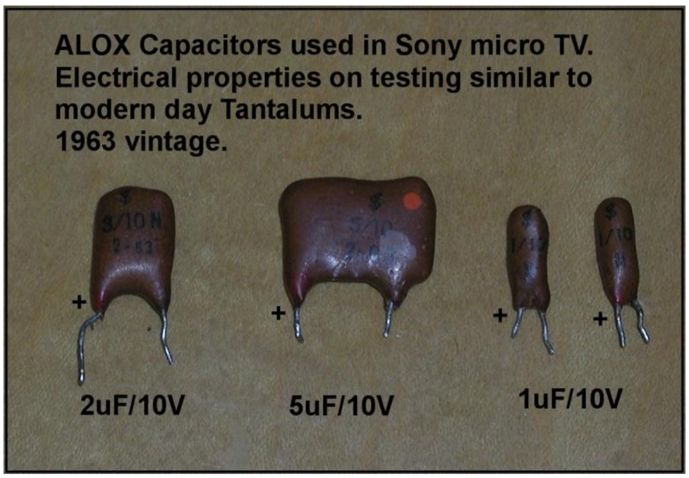
Finally on the topic of the vertical scan linearity; I think it was a pretty astonishing feat that Sony came up with a vertical oscillator and scan circuit that used only three transistors in total.

So it is really not that surprising that the adjustments and mix of currents at the input to the two stage vertical scan amplifier (transistor X17 and output stage X18) is a little critical for a linear scan.

A more modern TV would contain at least two or three or more transistors. So I cannot but admire the genius and simplicity and economy of what Sony did with the vertical oscillator and scan amplifier. Later though they also changed the design, see below.

The ALOX Capacitors:

These capacitors are very interesting. They are potted in a brown resin, somewhat reminiscent of a modern day Tantalum capacitor, but they have a wax coating over the resin too. They appear to have a Logo I cannot recognise, it has some similar features to the Siemens logo, but it is not exactly the same, I copied it as best possible for the image below:



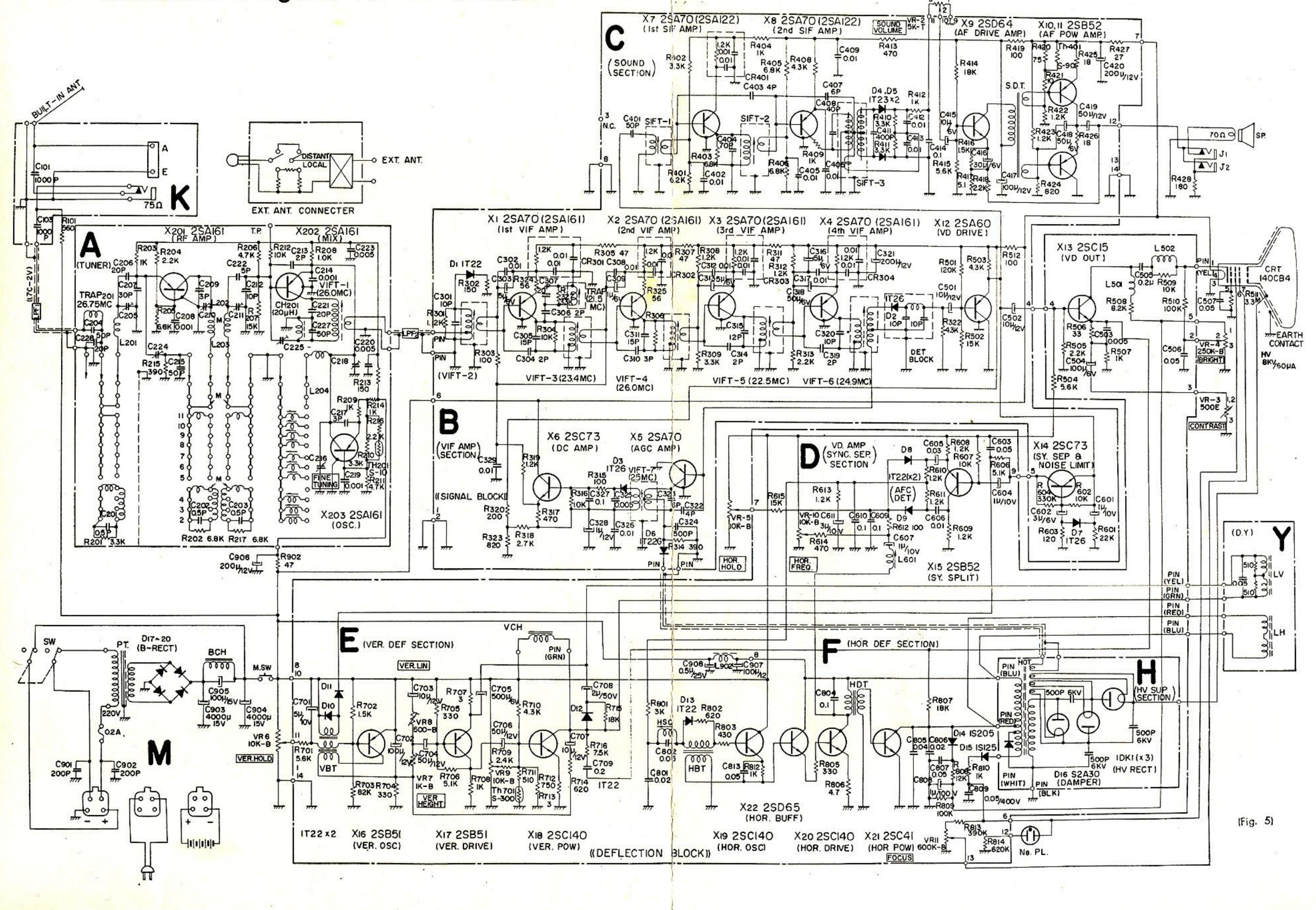
On testing the leakage properties of these Alox capacitors, they are very similar to a Tantalum capacitor.

It is interesting that Sony used these in their sets, since they had the advanced technology to make Silicon transistors and might have made their own capacitors if they had wanted.

The fact these capacitors are all working nearly 60 years later says a lot. Probably they are an Aluminium Electrolytic, but the similar leakage profile to Tantalum caps is very interesting. The 5uF one read 6uF on my meter.

Even though these capacitors tested perfectly, I replaced the 2uF and 1uF ones with non electrolytic Wima MKP 50V types (the pink-red color ones seen in the photo of the deflection board) and the 5uF with a 6.8uF 50V Tantalum, to hopefully avoid any future issues, but who knows, these vintage Alox capacitors may well still be better than modern manufacture ones. 57 years is a pretty good test window.

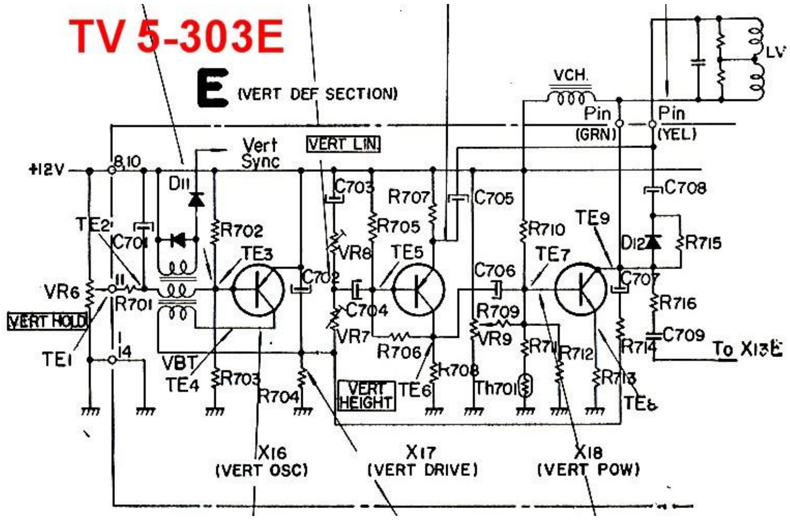
Schematic Diagram for TV 5-303E

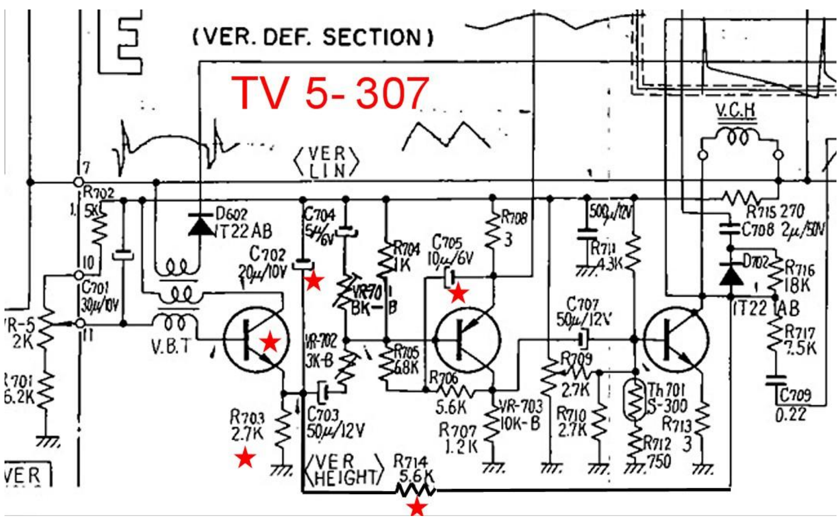


Other Notes:

In Sony's next model, the TV 5-307U, it sported a UHF tuner. However it seems at this time that Sony, like myself, might not have been entirely happy with the design of the vertical scan oscillator and amplifier in the TV 5-303.

Sony modified the positive feedback loop design in the 5-307 (as I had to in my 5-303, but in a different way eliminating C707) and they went to a Silicon oscillator transistor and lowered the value of the sawtooth capacitor C702 from 100uF to 20uF and used a higher value charging resistor, 2.7k vs 330R. On top of this they modified the collector to base bias resistor R706 on the input transistor X17. Split now into two resistors with a 10uF capacitor to bypass the AC component off the negative feedback. This has the effect of increasing the signal AC gain of the input (drive) transistor X17. Also some other value & transistor type changes. The two circuits are shown below for comparison:



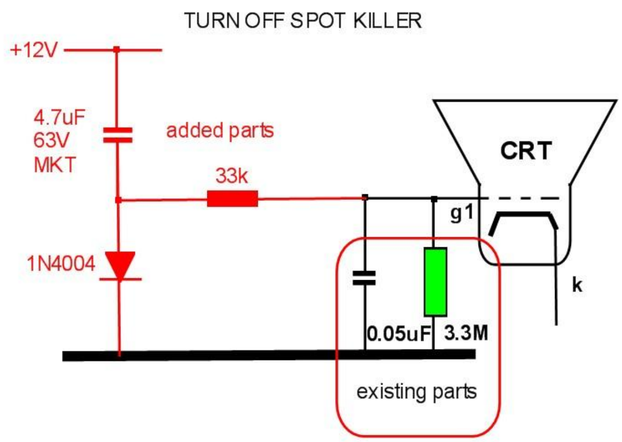


Some final points to add, if this set is run of a 12V external battery it is very important that at least a 1 to 1.5 Ohm resistor is placed in series with the battery. This is also shown on some of Sony's diagrams, but not all. The reason for this is that a lead acid battery can have a very low internal resistance, especially a car battery. When the heater in the CRT is cold and has a very low initial resistance, the surge current can be extreme enough to bright flash part of it and even fuse it. With the resistor, in conjunction with the large value filter electrolytics in the set, with the resistor present, the CRT heater gets a softer start and the voltage applied to it rises more slowly. One other method than can help is a resistor in series with the CRT heater

Also, on my set and this is issue affects many TV's of the era: At turn off, when the CRT's scan stages initially stop the deflection, the CRT heater is still warm and the CRT's electrode voltages can stay present for a while. The intense energy applied to the phosphor near the screen centre can damage it over time and it loses its sensitivity in that area. Many TV and VDU manufacturers organised “turn off spot killers” to prevent this issue. The other thing that helps is to remember to turn the brightness to zero, before de-powering the TV.

So for this little set, I added as I often do if it is not already there, a small turn off spot killer circuit. It simply works by charging a capacitor from the power supply via a diode. The impedance of this pathway is low so that if the TV gets turned of & on rapidly (or has a bad power supply connection) the capacitor charges very quickly. Then when the power is switched of, the TV’s 12V supply collapses fairly quickly to zero as it still has all the loads on it. This takes the diode side of the capacitor negative with respect to ground by about -12V at turn off, then after a while, the capacitor discharges via the 33k & 3.3M resistor. This creates a long duration negative voltage pulse at the CRT grid at turn off, helping to extinguish the beam current, especially if the user has not turned the brightness control down first.

These three components are simply mounted on the lower pcb connector pins where the existing 3.3M resistor and 0.05uF capacitor reside. There is plenty of room there.



Another simple method that works is to increase the charge storage on the video amplifier circuit’s power rail (in the case where the video amp drives the cathode and is direct coupled) by powering it via a series diode and using an electrolytic filter capacitor on the supply rail, then at turn off, the cathode voltage stays high for a while, helping to extinguish the beam that way. In the case where it is AC coupled the same idea works with some charge storage on the brightness control circuit in the cathode.

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