The 1987 vintage CONRAC monochrome avionics video monitor.

Dr. H. Holden. Sept. 2017. **(Update Oct. 2017- Source of Black Level Controller discovered –see article end)**

The video monitor described in this article is the most exceptional monochrome video monitor I have ever encountered.

As this article will show, every aspect of the design & build of this monitor, (614 - 14 inch model) is uncompromising, right through from the mechanical engineering aspects and the materials used, to the circuit design and the component types used.

Much of this relates to the fact that the monitor was manufactured for Avionics applications so the components, which are all mil spec types, are of outstanding quality. It appears as though no expense was spared making it and one wonders what the original application might have been.

Of note; this monitor does not contain a single electrolytic capacitor. They are all mil spec axial Tantalum types. As nearly everyone in electronics now knows, it is the electrolytic capacitors that are the nemesis to the longevity of most commercial electronic equipment.

One of the attractive features of this monitor is the uncluttered and austere nature of its front panel controls (only two controls - brightness & contrast) and the appealing rectangular faced 14 inch CRT. It has a “Retro” appearance and looks like it may well have escaped from a 1960’s vintage Sci-Fi television show, something like Voyage to the Bottom of the Sea, where it would have looked quite at home mounted in one of the Seaview Submarine's control panels. Or perhaps a control panel on the Flying Sub. Or maybe part of the equipment on the Jupiter-2 flying saucer, in the TV series Lost in Space.

I acquired two of these monitors as NOS parts which had been in their storage bags for over three decades. The bags had protected them and they were free from damage or corrosion.

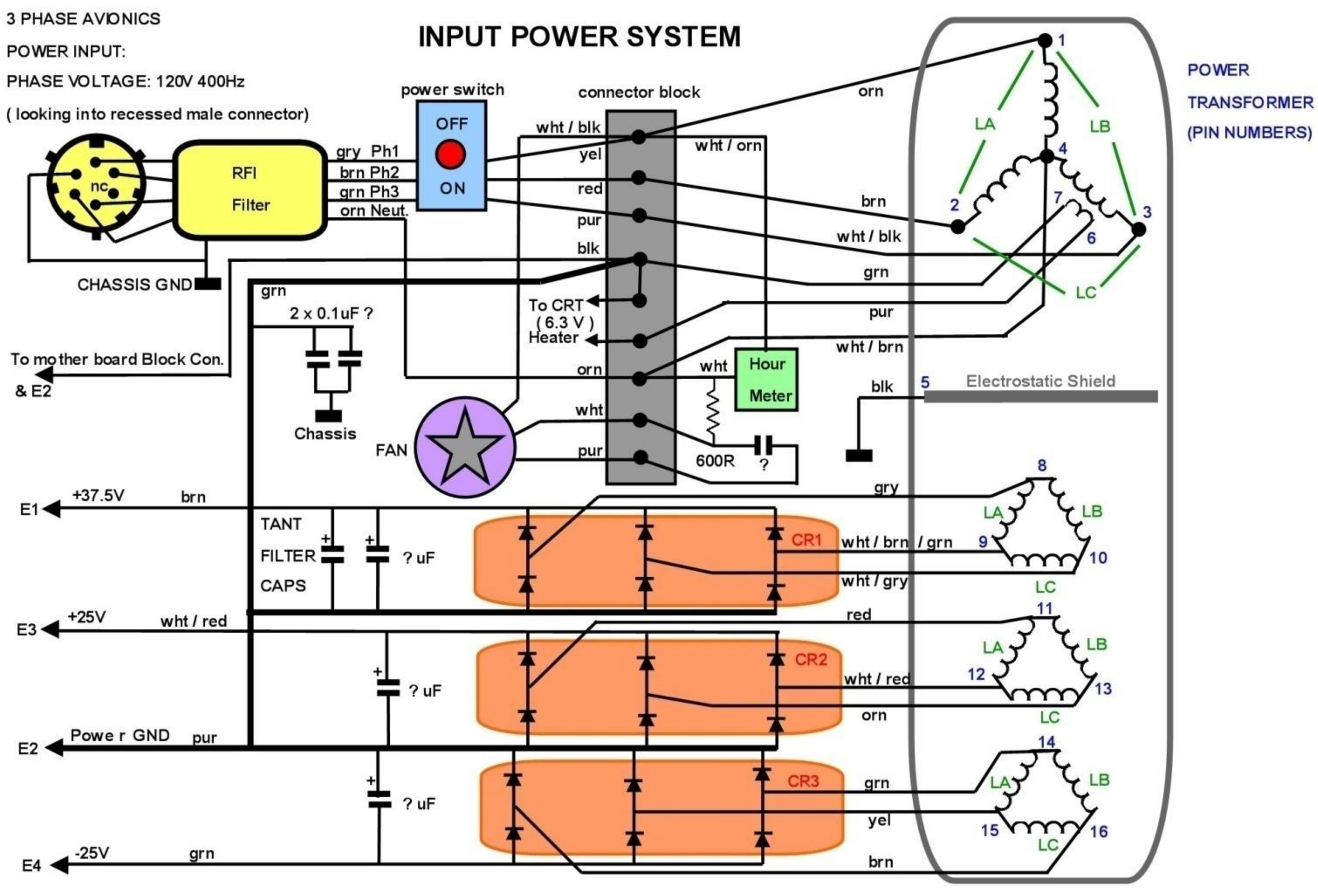
One problem with this sort of avionics monitor is, unlike most commercial monitors, there is no service manual or schematic readily available. There will be one out there but I can't locate it. The only way to safely make it work again is to sit down and patiently copy out the circuitry by hand to determine the power supply requirements and other features.

Firstly I documented the power supply and being an avionics monitor it was designed to be powered by 400Hz three phase 120V (per phase). Or another way to specify this is a 400Hz 208V 3 phase *line voltage*. An information test data sheet the monitor came with suggested the power consumption was 50 Watts on test and 80W maximum. It looked from this sheet that the monitor had been very carefully tested and inspected before it left the wonderful Conrac factory in 1987, but there was little other useful information documented there.

I initially did not have this power source in my workshop (but I quickly built one, see end of article). It was obvious though, after documenting the power supply sections, that this monitor could be powered by three added compact mains operated switch-mode DC power supply units that could be put in the monitor's base. I decide not to do that though, because I found the nature of the 3 phase system more interesting and I wanted to leave it original.

The circuit below shows the monitor's power supply section. By applying a small diagnostic voltage at the power inputs I was able to determine the likely output voltages of the power transformer and how its windings were configured. This was because I knew what the voltage of one secondary winding should be; 6.3V to power the CRT's heater. The primary of this power transformer is *wye* connected and the secondaries are *delta* connected.

The values of the components such as capacitors and some resistors were not easily discernable from their markings, so in those instances I have left question marks on the diagrams:



The 400Hz power source is also used to power the hour meter and the cooling fan. The cooling fan is a single phase 400Hz type. The fan runs at 10,200 RPM and sounds like a loud jet engine, so I disconnected it and I arranged better convection cooling initially.

Of note there is a very impressive large input 3 phase power filter unit and a three pole hermetically sealed power switch.

All the wiring is multi-coloured Teflon coated. The delta outputs from the very compact and shielded 3 phase power transformer are full wave rectified. Since it is full wave 3 phase 400Hz, the ripple voltages are very low. Much less filter capacity is required than in a 50Hz or 60Hz power system. This is one of the reasons why the designers were able to avoid electrolytic capacitors in the power supply section, where normally they are always required for semiconductor based video monitors.

The input connector is a standard Amphenol part and I was able to acquire one easily on ebay to manufacture a power cable.

The designers at Conrac decided to subdivide the design of the monitor’s electronics into 6 basic parts:

LVPS. (low voltage power supply pcb)

VERT. (vertical deflection pcb)

VIDEO. (video signal processing and CRT drive)

HORIZ. (horizontal deflection & drive to EHT unit)

MOTHERBOARD. (for the above 4 boards)

EHT. (A separate enclosed and shielded EHT unit).

Each of the four pcb's that live on the motherboard plug into it with a high quality connector with gold plated pins and the 4 boards are supported and held in place by an aluminium frame. Two pairs of thumb nut stainless steel locking screws secure the four boards. Each board has a similar design philosophy:

The boards are 1/8" thick fibreglass (as is the motherboard). Extensive use of ground planes are used in the track design. The upper part of each board is fixed to a 1/8" thick treated aluminium metal plate. The plate acts as a heat sink for power semiconductors where required and as the handle to withdraw the pcb from the carrier when the release screws are undone.

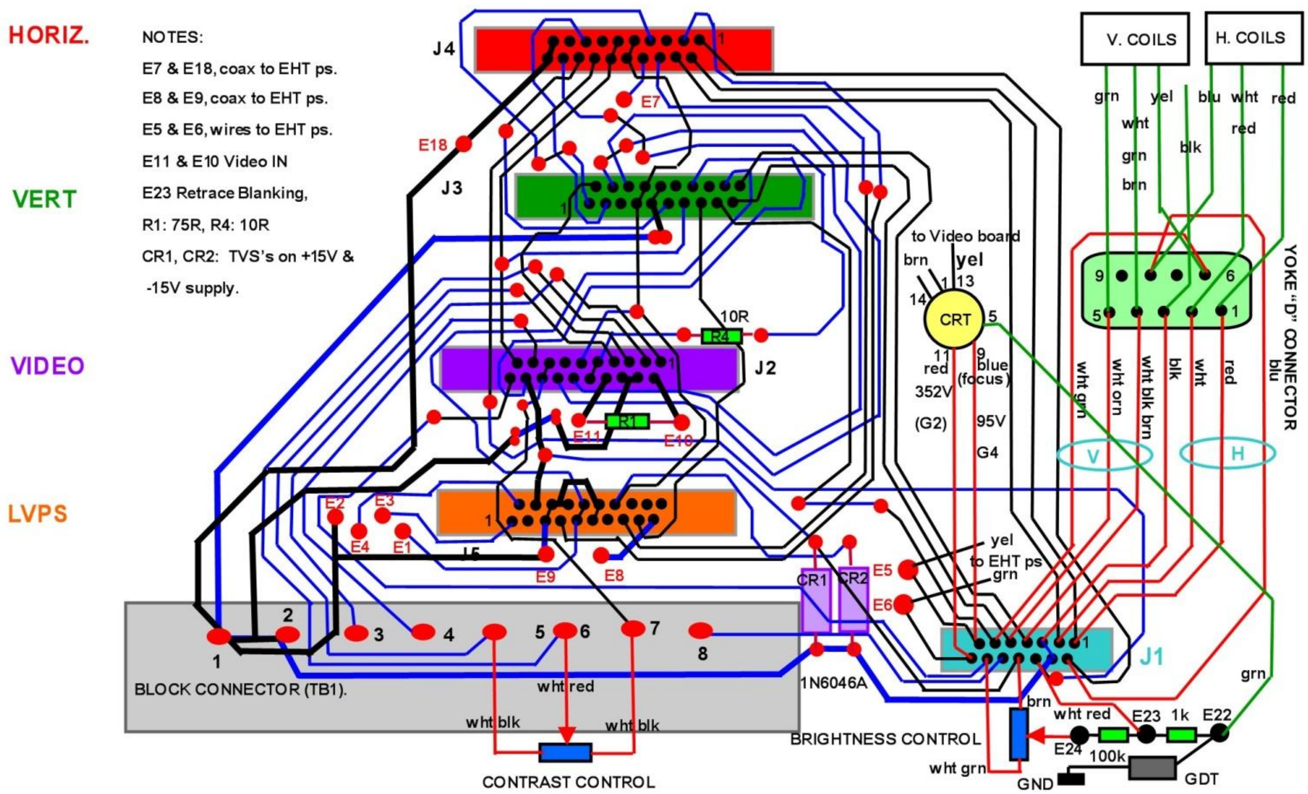
I realised that it would require that each pcb would have to be documented as there were quite a few preset controls. Two of these would obviously include the Horizontal Hold and Vertical Hold controls and to try to find these by experiment could upset other adjustments.

I decided that the best initial move would be to document the motherboard which provides interconnects between all of the other boards. The easiest way to do this was simply by documenting the tracks. It is a dual sided pcb. It also contains additional connectors, for the deflection yoke for example.

I considered it would also help if I assigned colours to the connectors and each of the 4 boards. That would then make it easier to see which pin on a board went to which pin on another board by using coloured pin labels.

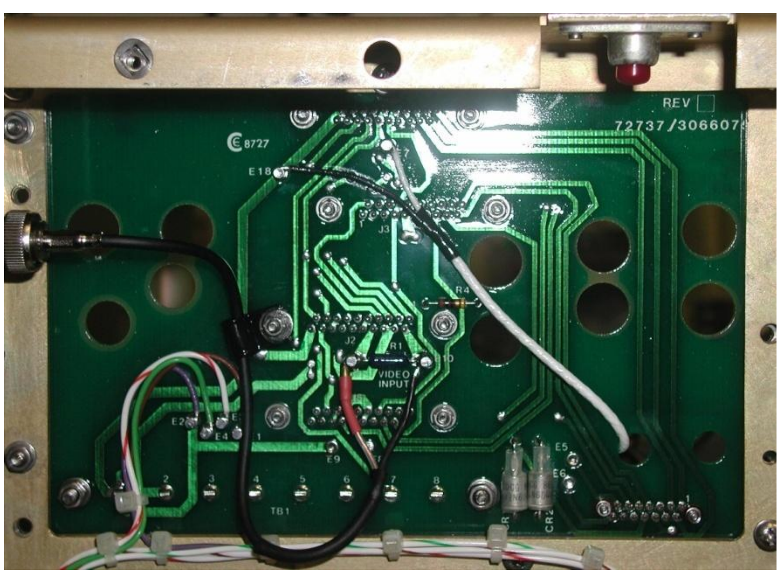
The motherboard diagram is shown below:

MOTHER BOARD Bottom View of connectors. Black tracks, bottom, blue tracks top, Red = Through holes.

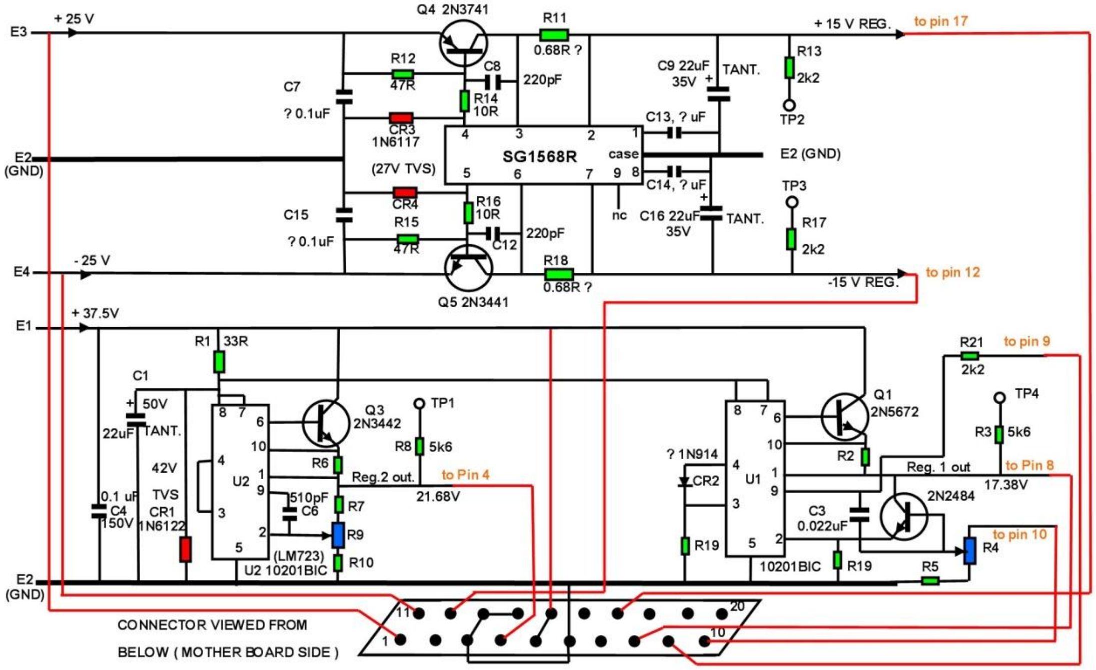


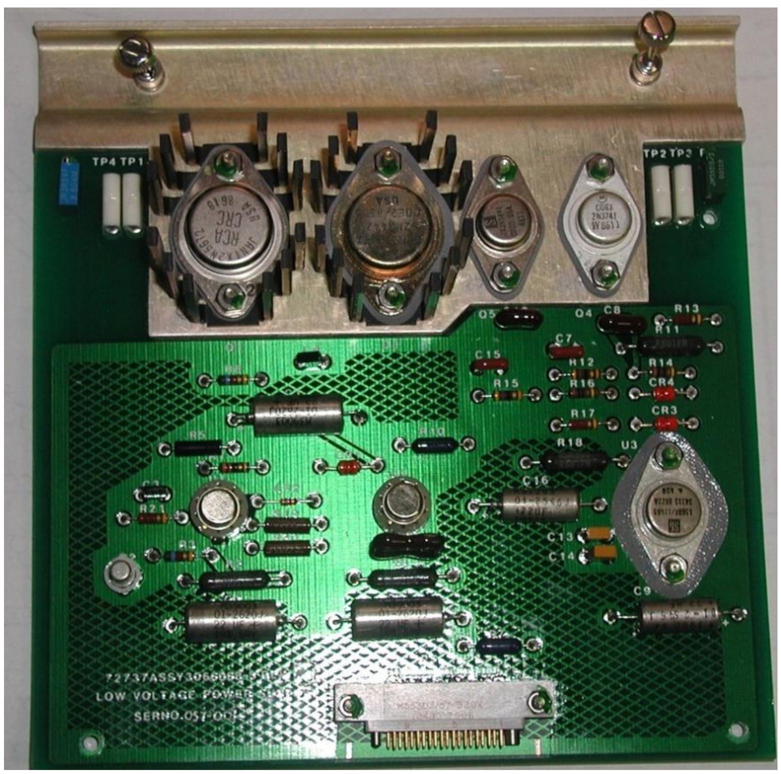
Interesting features include the TVS diodes (Cr1 & CR2) on the power supply rails from the LVPS. Also a GDT (gas discharge tube) protecting the grid circuit of the CRT (these latter items are on the chassis near the brightness control on the front panel). Connector J1 passes it leads to another separate D connector (light green) where the yoke plugs in.

The photo below shows the bottom view of this board:

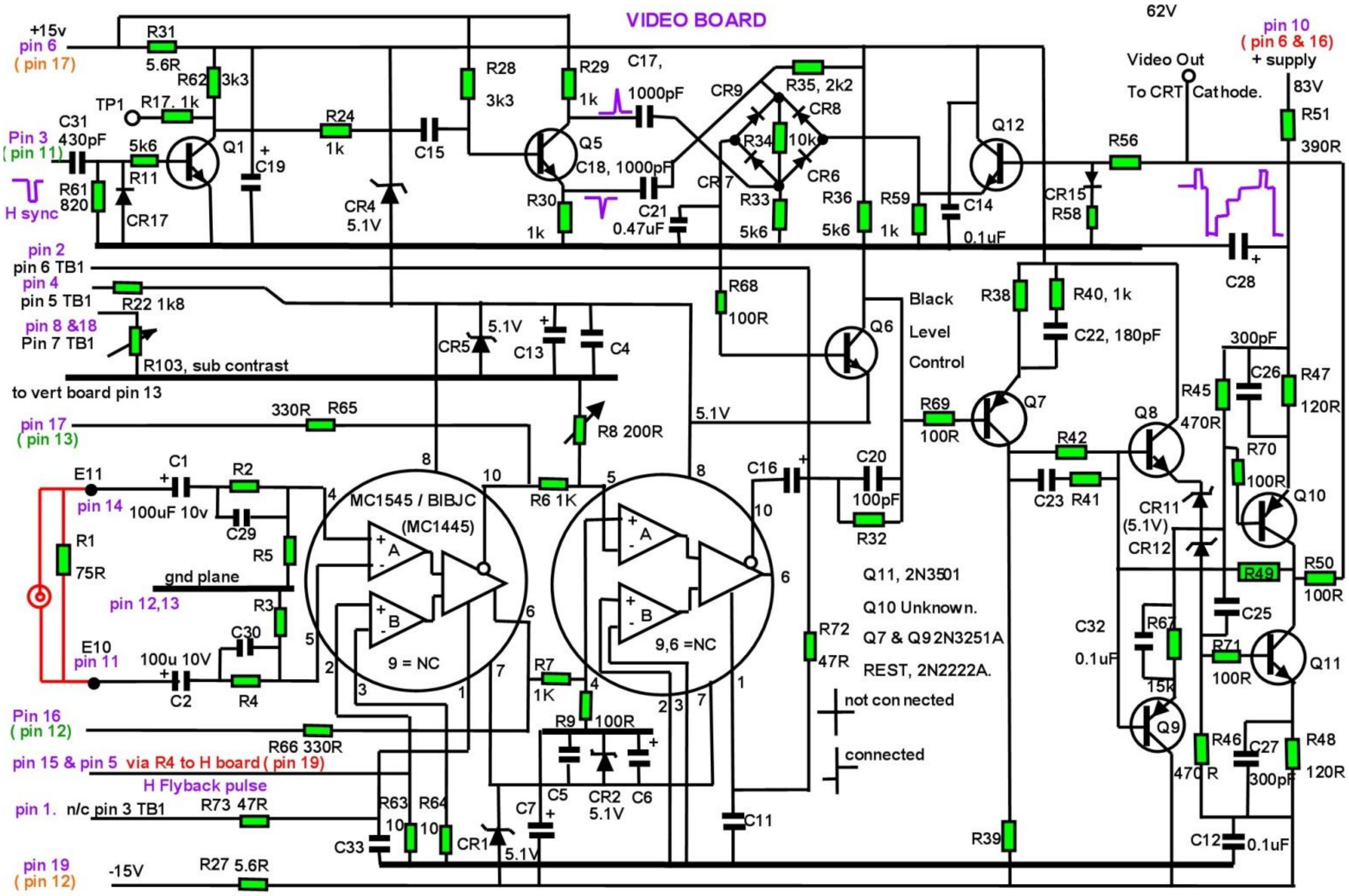


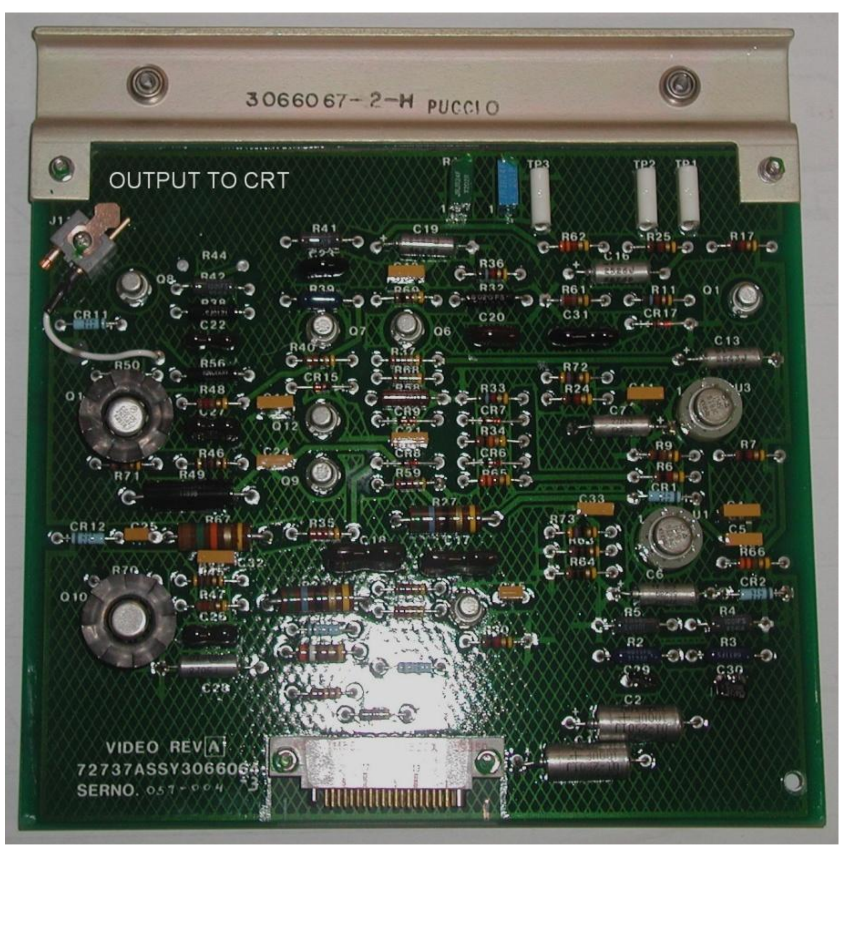
LVPS: LOW VOLTAGE POWER SUPPLY.

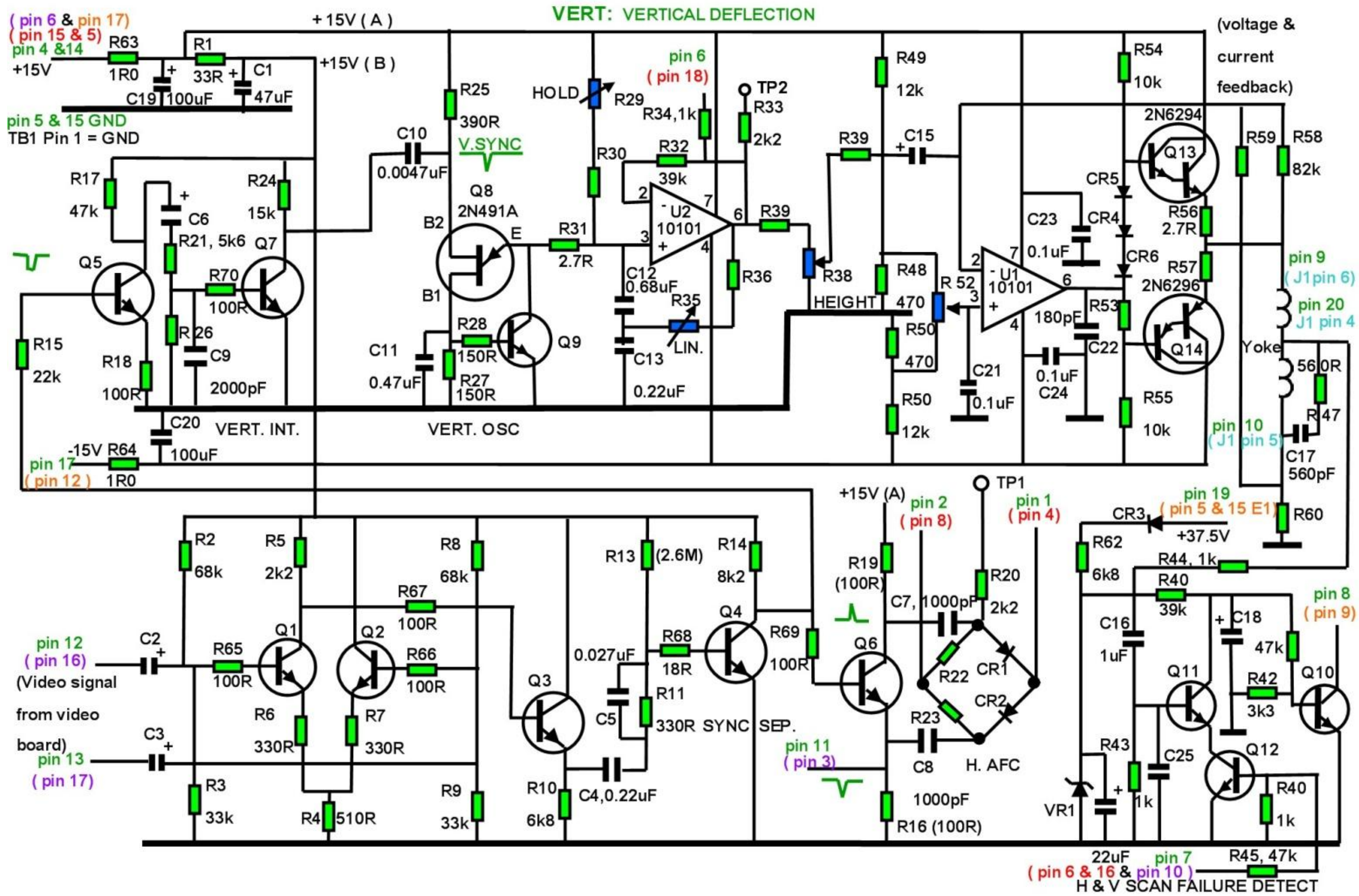


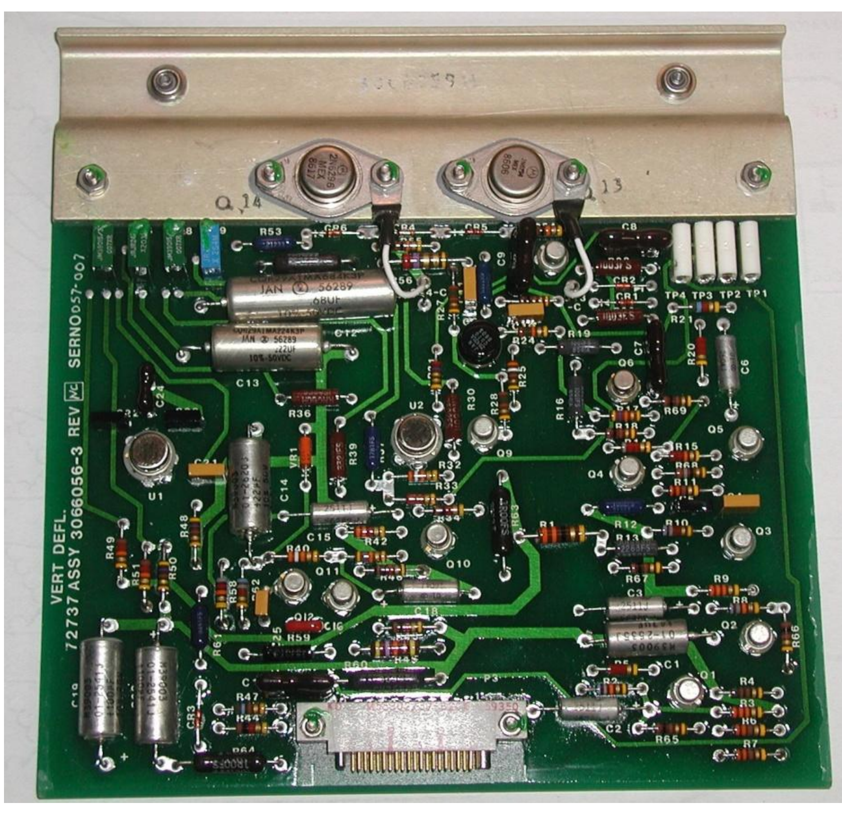


Notice how the pcb's metal handle used to withdraw it, also forms part of the heat sinking for the power devices.

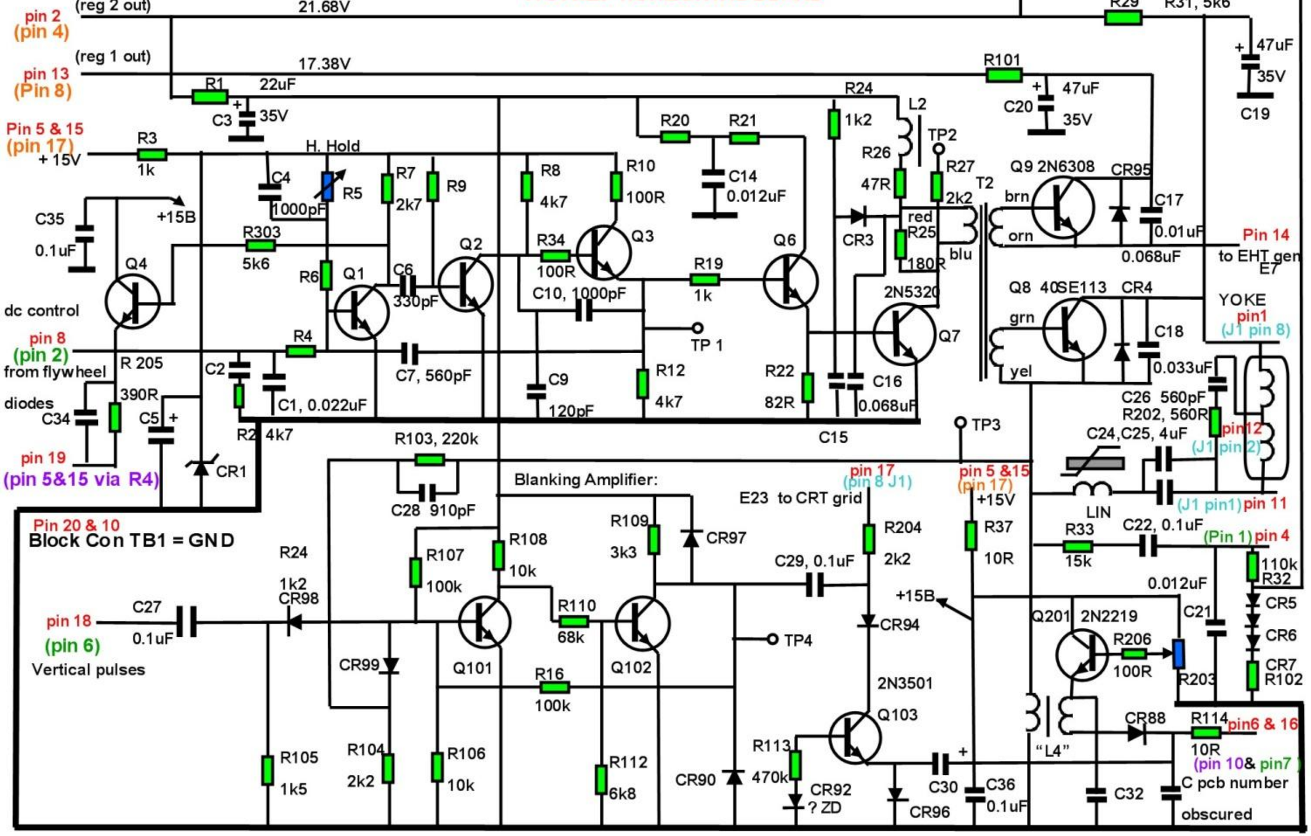

VIDEO BOARD
+15v
pin 6
(pin 17)
R31
5.6R
R62
3k3
TP1
R17, 1k
C31
430pF
Pin 3
(pin 11)
5k6
R11
Q1
C19
R24
1k
C15
R28
3k3
R29
1k
C17,
1000pF
Q5
C18, 1000pF
R30
1k
C21
0.47uF
CR9
R35, 2k2
CR8
R34
10k
CR7
CR6
R33
5k6
R36
5k6
R59
1k
C14
0.1uF
Q12
62V
Video Out
To CRT Cathode.
pin 10
(pin 6 & 16)
+ supply
83V
R51
390R
R56
CR15
R58
R61
820
H sync
CR17
CR4
5.1V
pin 2
pin 6 TB1
pin 4
pin 5 TB1
R22 1k8
pin 8 &18
Pin 7 TB1
R103, sub contrast
to vert board pin 13
CR5
5.1V
C13
C4
R68
100R
Q6
Black
Level
Control
R38
R40, 1k
C22, 180pF
C28
300pF
C26
R47
120R
R45
470R
pin 17
(pin 13)
330R
R65
R8 200R
5.1V
R69
100R
Q7
Q8
R42
C23
R41
R70
100R
Q10
E11
C1
R2
pin 14
100uF 10v
C29
R1
75R
gnd plane
R5
pin 12,13
R3
C30
E10
pin 11
100u 10V
C2
R4
MC1545 / BIBJC
(MC1445)
9 = NC
R6 1K
C16
C20
100pF
R32
9,6 =NC
CR11
(5.1V)
CR12
R49
R50
100R
C25
Q11, 2N3501
Q10 Unknown.
Q7 & Q9 2N3251A
REST, 2N2222A.
C32
0.1uF
R67
15k
R71
100R
Q11
R72
47R
not connected
connected
R7
1K
R9
100R
Pin 16
(pin 12)
R66 330R
pin 15 & pin 5 via R4 to H board (pin 19)
H Flyback pulse
pin 1. n/c pin 3 TB1
R73 47R
R63
10
R64
10
C33
C7
CR1
5.1V
C5
CR2
5.1V
C6
C11
Q9
R46
470R
C27
300pF
R48
120R
R39
C12
0.1uF
pin 19
(pin 12)
-15V
R27 5.6R

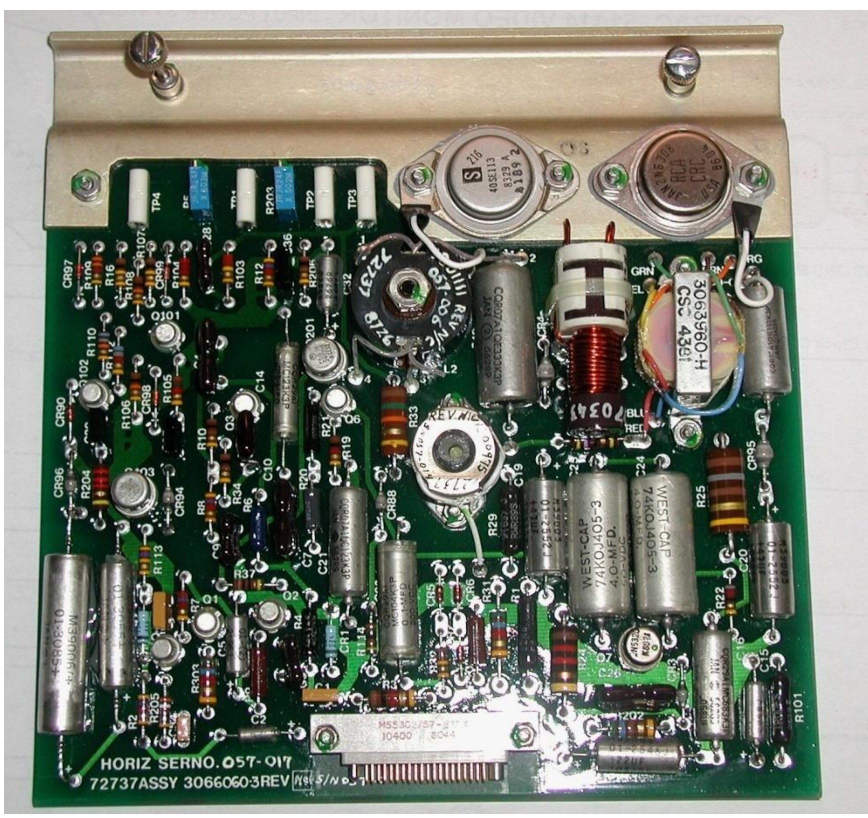

3066067-2-H PUCCIO
OUTPUT TO CRT
VIDEO REV A
72737ASSY3066064
SERNO.


VERT: VERTICAL DEFLECTION
+15V (A)
+15V (B)
(pin 6 & pin 17)
(pin 15 & 5)
pin 4 &14
+15V
pin 5 & 15 GND
TB1 Pin 1 = GND
VERT. INT.
VERT. OSC
V.SYNC
HOLD
HEIGHT
LIN.
SYNC SEP.
H. AFC
(voltage & current feedback)
2N6294
2N6296
2N491A
Yoke
pin 9 (J1 pin 6)
pin 20 J1 pin 4
pin 10 (J1 pin 5)
pin 12 (pin 16) (Video signal from video board)
pin 13 (pin 17)
pin 17 (pin 12)
-15V
pin 11 (pin 3)
pin 2 (pin 8)
pin 1 (pin 4)
pin 19 (pin 5 & 15 E1)
+37.5V
pin 8 (pin 9)
pin 7
(pin 6 & 16 & pin 10)
H & V SCAN FAILURE DETECT
TP1
TP2


VERT DEFL.
72737 ASSY 3066056-3 REV
SERNO 057-007

HORIZ: HORIZONTAL BOARD





Interesting Circuit features:

Horizontal board:

In the horizontal output stage there are two independent output transistors, one for the horizontal scanning coils and one to drive the EHT assembly. The horizontal oscillator is DC controlled by the usual push pull AFC circuit where the diodes for this reside on the vertical deflection board. There is sensing of both H and V scan activity and the presence of the 37.5V supply, if any of these fail, regulator 1's output on the LVPS is shut down, this kills the drive to the EHT unit, shutting off the EHT.

The horizontal board also contains a proper blanking amplifier to ensure the CRT is properly blanked during H & V retrace time.

It appears as though Q103 (a 2N3501) has been configured as an avalanche device to protect the CRT's grid circuit. When the collector-base voltage is exceeded it clamps the grid circuit. This sub-circuit is not a common arrangement.

Vertical board: The vertical oscillator is based on a UJT which is not a common choice for this part of the circuit. However, this oscillator will lock immediately to 50Hz or 60Hz vertical syncs. The H scan oscillator also locks to 15,625 Hz or 15,734 Hz or 15,750 Hz, so the monitor displays either monochrome Pal or NTSC pictures without the need for standards switching, which is an unusual feature.

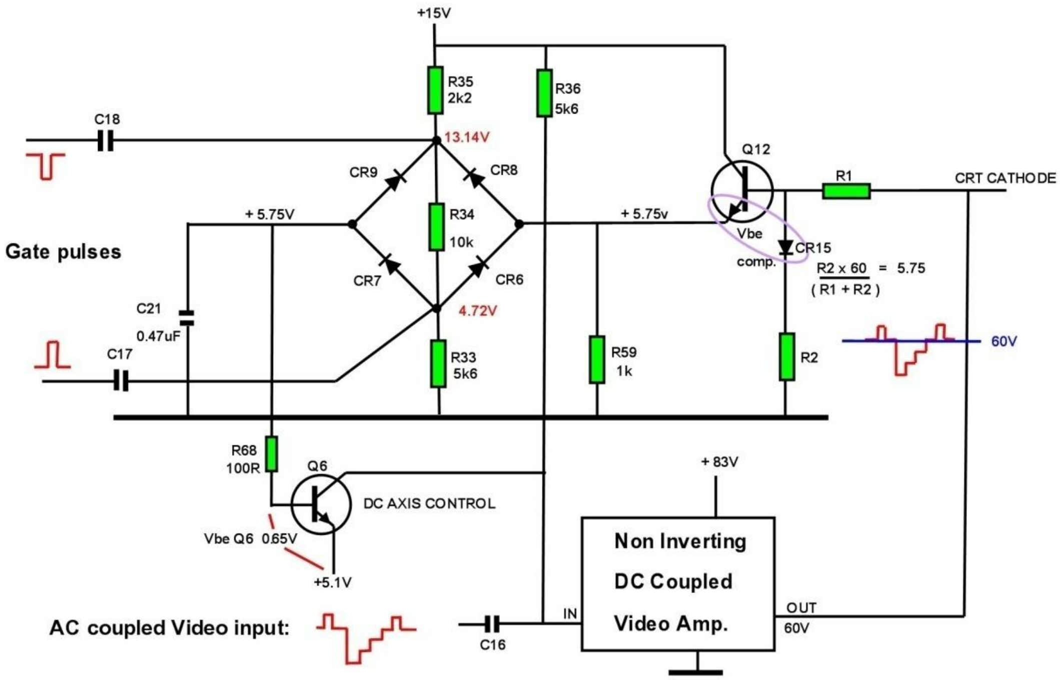
Video board: This board has a differential input for the video signal, presumably to limit the effects of ground loops. Use is made of the MC1545 (MC1445) differential amplifier as a gain control block.

This video signal CRT driver circuit has a unique black level stabilization system. The purpose of DC stabilizing the signal to a fixed voltage at its black level ensures that changes in picture contrast or content do not affect the black level and background brightness, which of course it always does if the video signal is AC coupled at any point prior to the CRT and this is not corrected for.

The common method to stabilize the black level is to do it with a DC restorer diode to stabilize the sync tip position (and the black level indirectly) or with a black level clamp circuit. This clamps the voltage after a coupling capacitor to a fixed value on the back porch of the signal just after the H sync.

However, the method used to perform black level stabilization in this monitor is different, surprising, creative and brilliant. So it is worth having a closer look at how it works. The partial schematic of the system is shown below:

BLACK LEVEL SAMPLE-HOLD



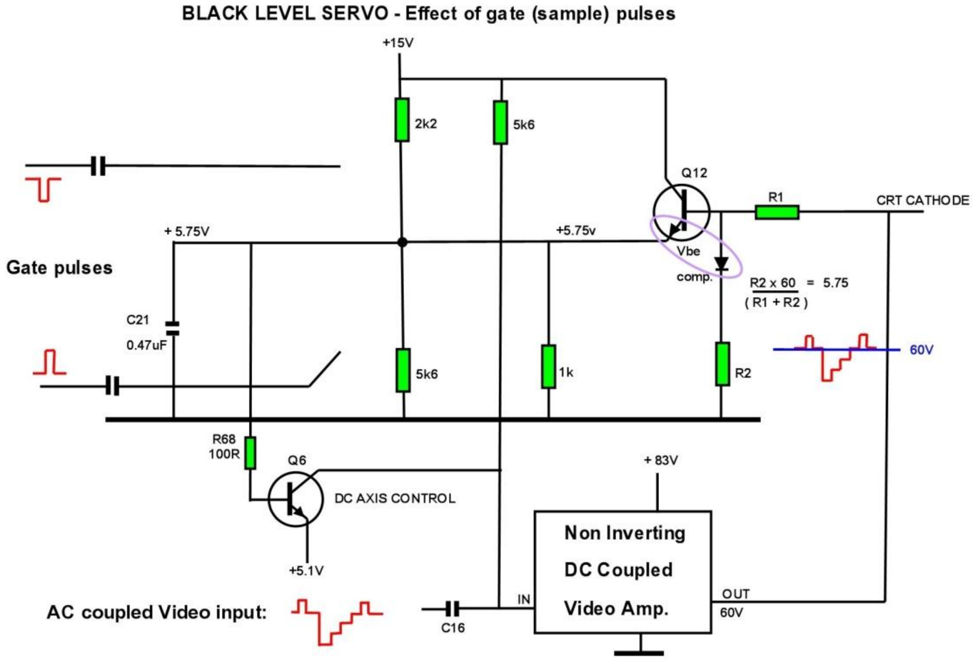
Differential gate pulses, coincident with the black level (just after the horizontal sync pulses) are coupled to a diode bridge. The output from the video amplifier (which feeds the CRT's cathode) is divided down by R1 and R2 and applied to the base of Q12. The diode CR15 in the base circuit temperature compensates the base emitter junction of temperature dependence of Q12.

The divided down video voltage is applied to CR6 and CR8. In the absence of the gate pulses, the 4 diodes in the bridge are reverse biased and are not conducting.

Q6 forms a voltage comparator. At first glance this is not obvious. The comparator's reference voltage is the threshold at which the base-emitter junction of Q6 starts to conduct. Because Q6 has a low resistance series base resistor (R68) and Q6's emitter is connected to +5.1V, the voltage during circuit operation on the junction of CR7 and CR9 appears stable at about 5.75V after activation of the diode bridge.

The video signal is AC coupled into the output amplifier's input by C16. However C16 would want to progressively charge up by R36. Any collector current via Q6 takes it the other way discharging C16. When the gate pulses are applied, the 4 diodes in the bridge conduct.

The best way to understand what happens, ignoring the small voltage drops of the diodes in the bridge, is to re-draw the circuit when all of the 4 diodes are conducting as they do when the gate pulses occur. The diagram below indicates what happens:



The divided down video output voltage is passed from Q12's emitter circuit to the loop filter capacitor C21. In practice because of the low value of R68, the voltage during operation across C21 appears stable. However, if for example the output voltage had climbed to say 65V the base current in Q6 increases, therefore its collector current increases discharging C16 and lowering the video amplifier's input voltage, returning the output voltage to the fixed value of 60V during the black level or back porch period.

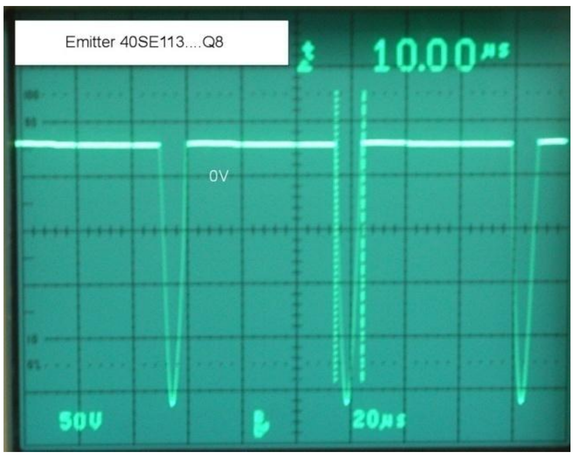
Likewise if the output voltage was lower than 60V at the moment of the gate pulses, then Q6's base current decreases and so does its collector current, allowing R36 to charge C16 to a higher voltage. The circuit stabilizes and "rests on the knee" of the conduction point of Q6's base-emitter voltage and this serves as the "reference voltage" for this feedback system or "black level servo system".

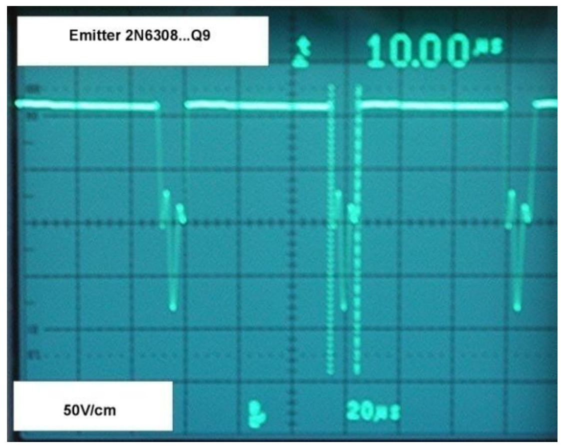
The circuit therefore is a type of gated negative feedback circuit and in this way the black level of the video voltage remains stable, regardless of the contrast levels or picture content. A possible advantage of this circuit, over a standard clamp, is relative immunity to noise pulses.

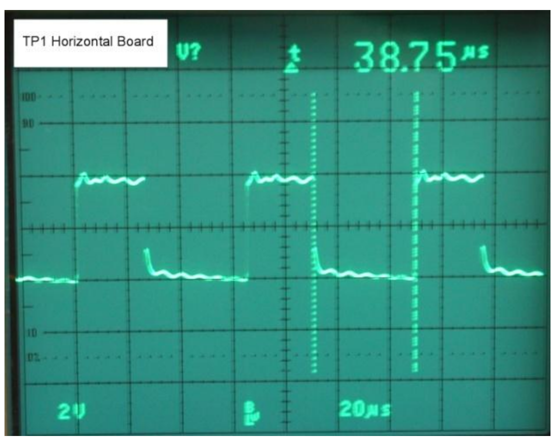
One might wonder what happens if the gate pulses disappear in the absence of video signal or horizontal sync? It turns out they don't. This is because a horizontal pulse gets coupled from the H sync discriminator circuit via CR2 and the coupling capacitor C8 to the emitter of the sync phase splitter (Q6 on the vertical board). So the black level servo control system is still active in the absence of an input video signal. If it were not, Q6 on the video board would turn off and the picture tube cathode voltage would float up from 60V to 80V cutting off the beam.

Since there is no manufacturer data at hand I decided to measure voltages in the power supply system and document those on the schematics I copied out. Also some oscilloscope recordings of the important waveforms on the horizontal board, in case the monitor ever needed repairs. The interesting and good thing they did was to take the outputs from the emitter side of the HOT and EHT generating transistors Q8 and Q9 respectively. This means if you touch the transistor body (collector) by mistake you don't get a shock as the voltage is relatively low.

(Of note when a transistor's base-emitter is driven by a transformer and is isolated, the transistor's collector-emitter circuit can be placed on the high or the low side with respect to the power supply rails and ground)







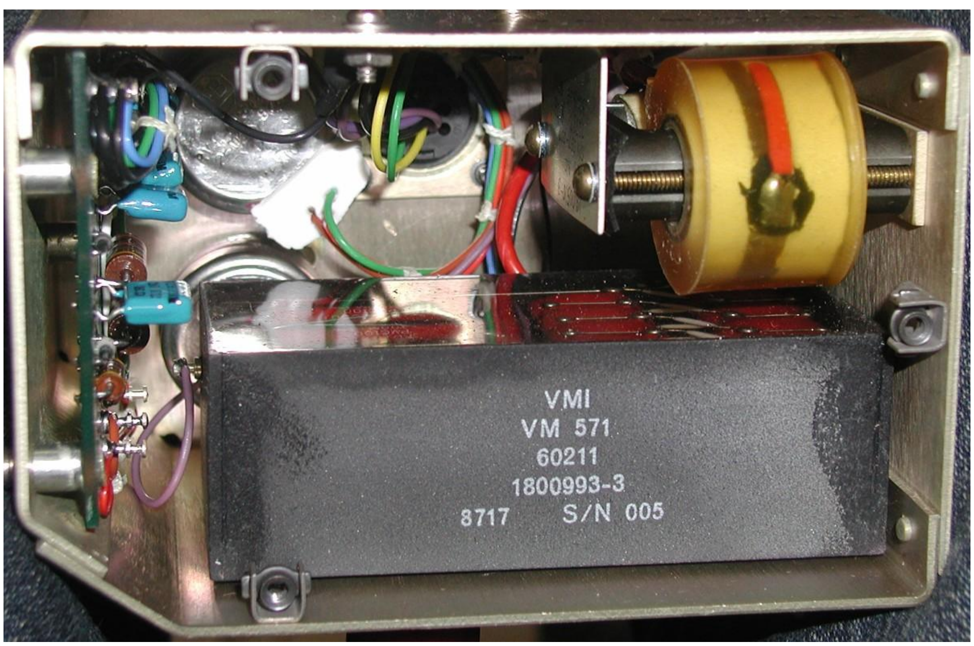
(The reason for the ripple on the horizontal drive waveform on TP1 is because the scope earth was placed on the monitor's chassis and not the ground connection of the circuit tracks on the H board).

EHT Assembly:

The EHT box contains no active devices. It has a few resistors and capacitors and the EHT (Flyback transformer). I have not documented its schematic yet. The photo below shows that apart from the transformer, the major component in it is a beautiful voltage multiplier to acquire 15kV, manufactured by VMI (Voltage Multipliers Inc). In my opinion, VMI make the world's best high voltage rectifiers and related products so I was very pleased to find this wonderful item inside the EHT box.

The high voltage overwind is perfectly potted in clear resin, so failure of that winding will be very unlikely too. Vintage television EHT transformers which were merely treated with wax often absorb moisture in this high voltage overwind, leading to failure.

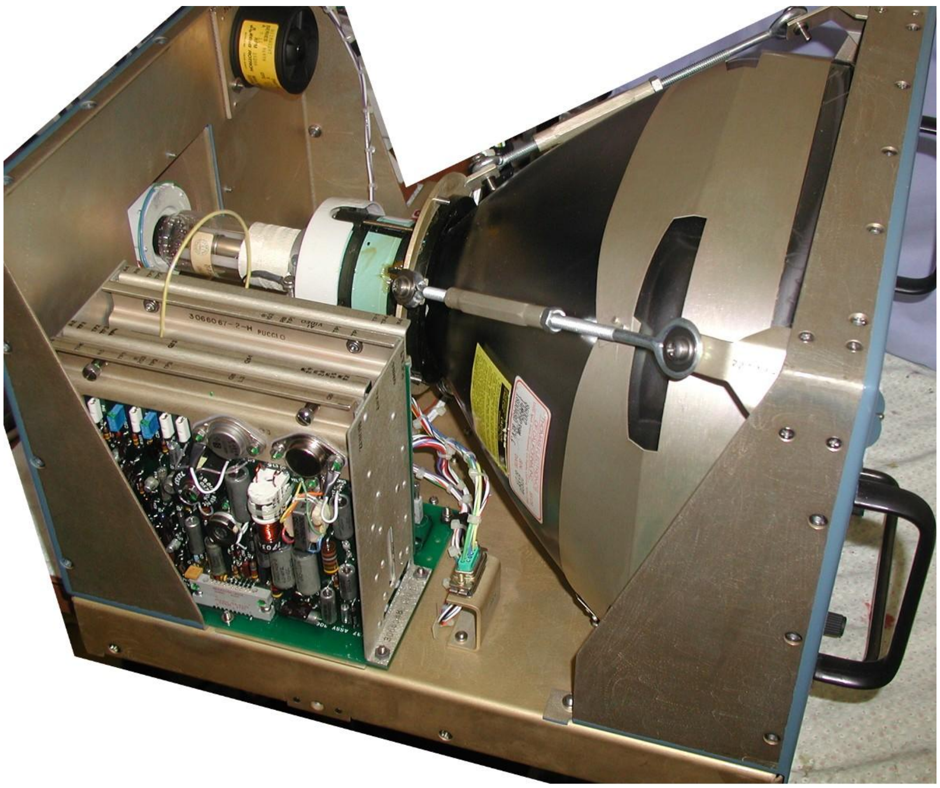
The photo below shows the inside of the EHT box, notice the interesting captive nuts that are used to secure it to the main chassis.



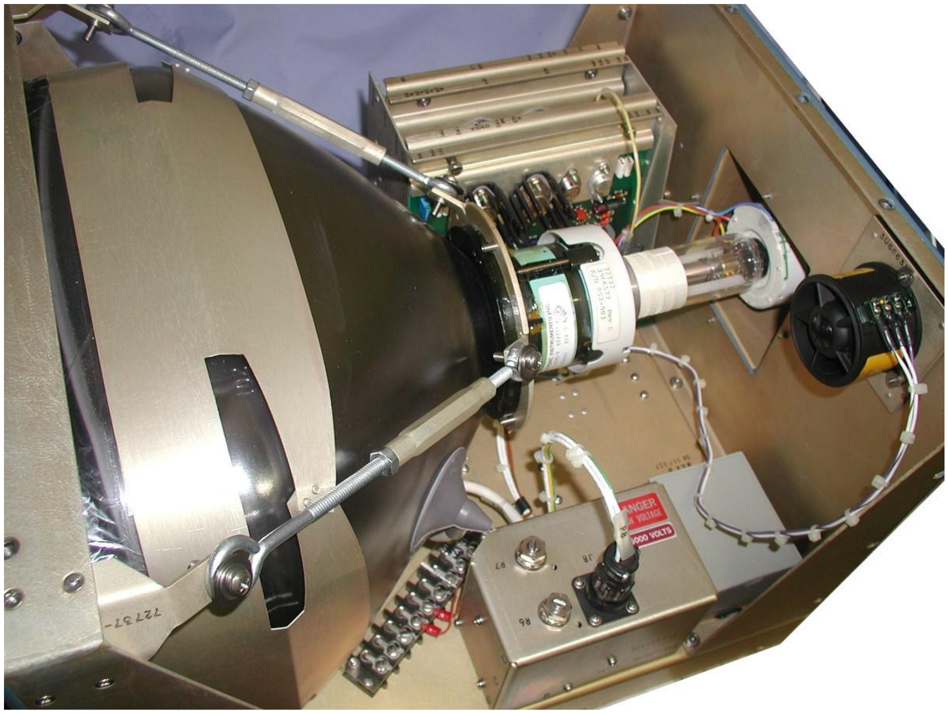
Mechanical Construction:

The monitor’s metalwork is treated Aluminium that looks like it has been passivated with Alodine or similar. There are no threads cut directly into this metal. Ever thread is a specialty type of captive nut assembly (see below) which all appear to be made of stainless steel and have an anti-vibration locking quality on the threads. Generally the threads are 6-32 UNC.

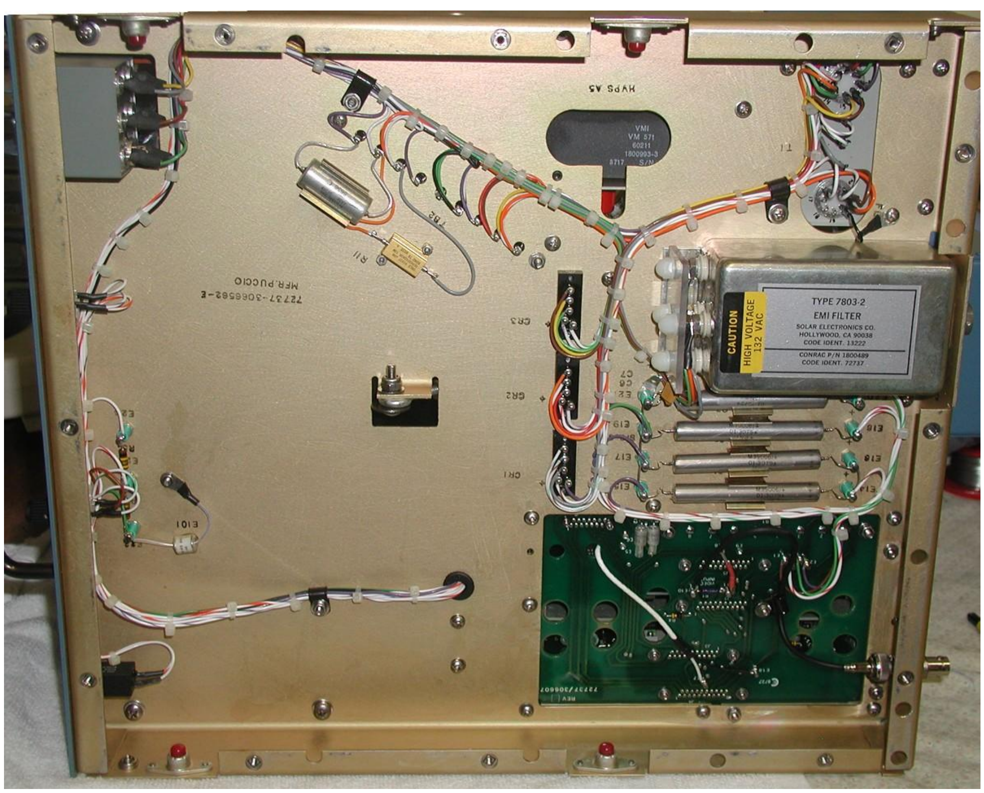
The photos below show the right hand and left hand side of the chassis top:



Three very robust threaded struts support the CRT & yoke mountings. The grey compact 3 phase power transformer sits just behind the EHT box.

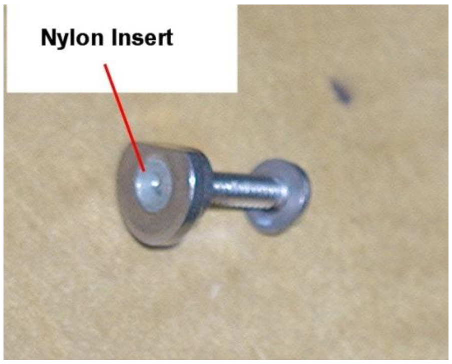


The photo below shows the chassis underside, which includes the large 3 phase power input EMI filter and the Stick Tantalum filter capacitors:



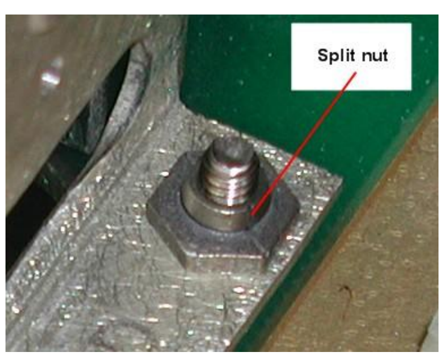
Fixing Devices:

I have never seen a monitor where such care and attention was paid to the fixing devices. The monitor has a very interesting array of captive & shake-proof nuts. As noted the EHT unit is held down by very interesting fixing devices. The cooling fan is held down by circular nuts which have a nylock insert and are shaped so that when the start to rotate they align themselves against the flange of the fan body and automatically stop rotating while the screw is tightened up:



Some of the nuts are standard pressed in types but the main array of nuts are a type where the cental nut has play in its pressed in carrier. These help to align the cabinet cover screws:

Some other nuts are pressed in and split types the give a constant force on the threads:

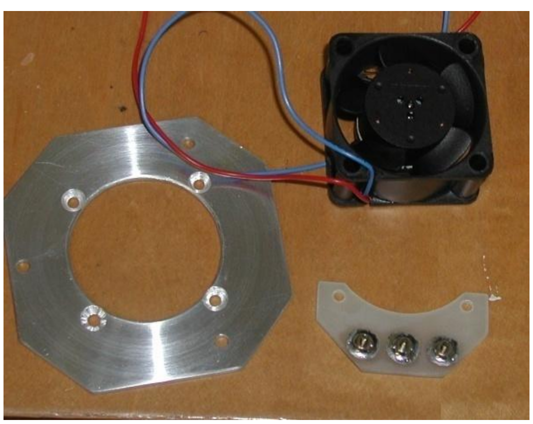


Cooling Fan:

The cooling fan is a compact powerful 120V single split phase 400Hz type with a capacitor to drive one of its windings:

Since it runs from 400Hz, the fan itself acts as a “speaker” and even if it is slowed down somewhat by reducing its drive voltage, it still makes a very loud sound. I decided in the end to change it to a 24V DC fan and run that from one of the monitor’s 24V DC supplies. I selected a smaller fan with low noise (18dB).

Since the monitor dissipates 50W of heat it is important not to let hot air stagnate inside it. There are good screened ventilation holes in the cabinet sides. The DC fan does a good job of clearing the air in the case. Plus I added some additional convection ventilation by spacing the CRT rear cover away from the back panel to create a good ventilation slot. So that the new fan could mount easily and use the same lugs, I machined a terminal board with screw connectors (from PCB material) and an adapter plate, so it could be attached with the existing mounting and terminal screws:



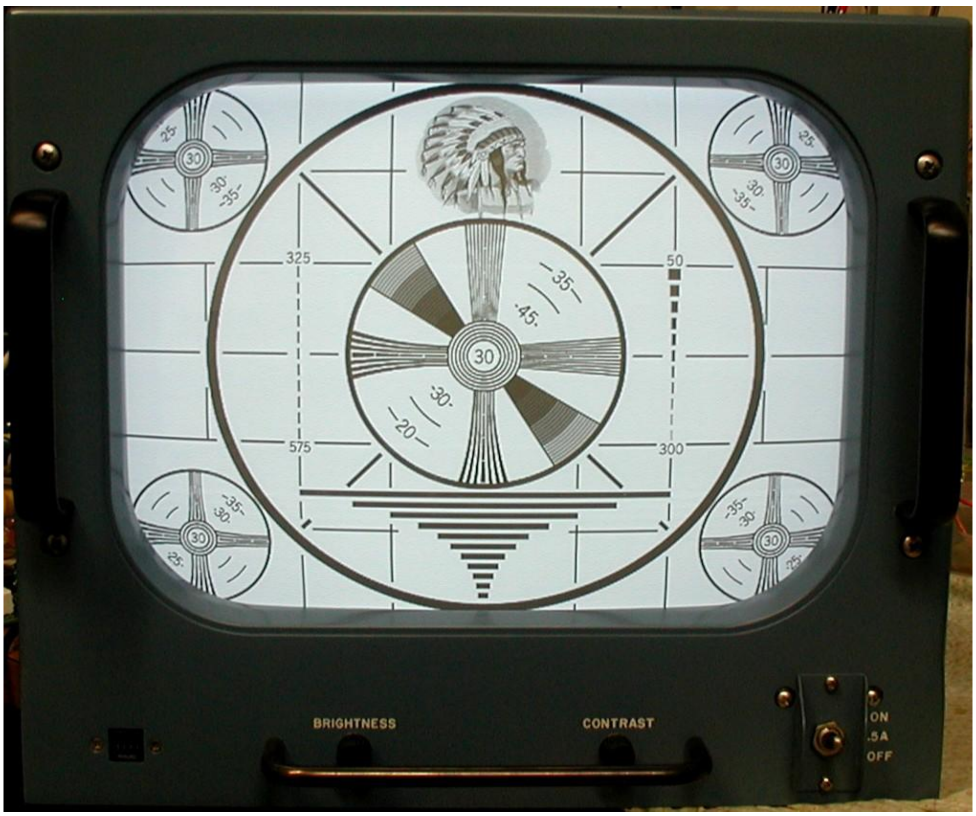
Deflection Yoke:

The deflection yoke in this set is a masterpiece of quality electro-magnetic engineering. It contains raster geometry correction magnets built into it. It is made by a specialist company Syntronic Instruments.

Original CRT:

Since the original CRT type in this monitor is a P39 phosphor or green type for radar applications, I changed it to a 14BAP4 type white CRT. This required a new CRT socket too but the tube types and electron gun are otherwise exactly compatible.

I took some photographs of the images produced. The video amplifier has a very wide bandwidth and excellent high frequency response so the images are crystal clear. The screen (camera) photos do not do them justice.

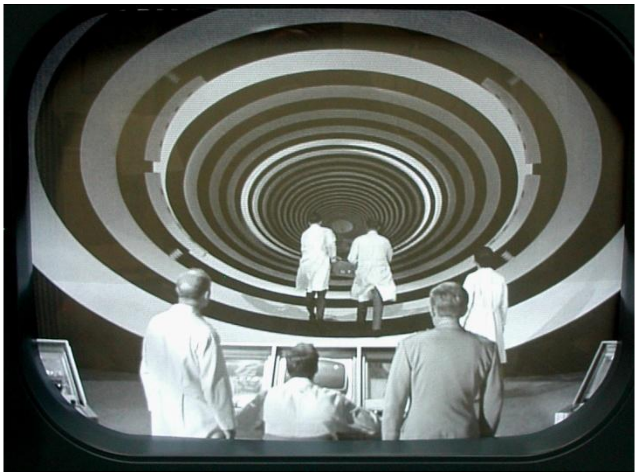


The image above is the famous American Indian Head test pattern, programmed as a 625 line monochrome image into Richard Russell’s programmable test card generator.

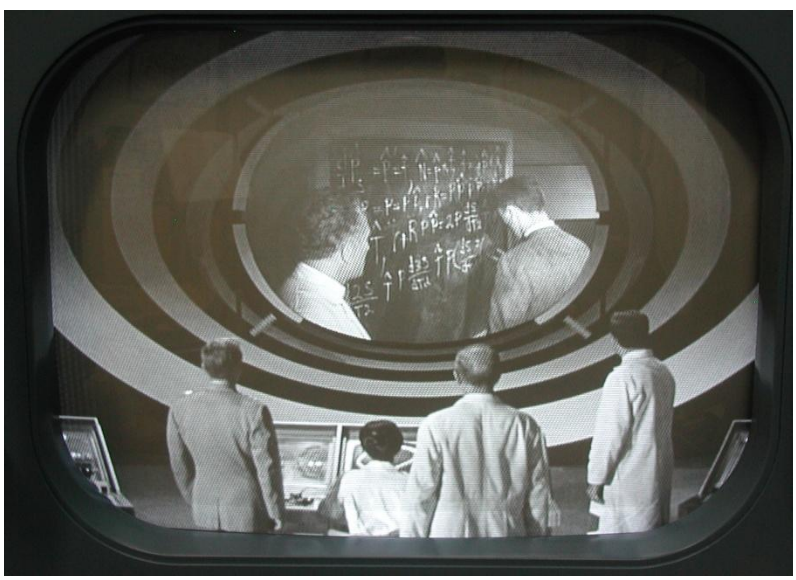
The images below are still frames taken from Voyage to the Bottom of the Sea.

Two images below are from the episode “Menfish” where a lunatic doctor decides to create a “manfish” and he gets into a fight with scuba divers:

The images below show still frames from Irwin Allen’s Time Tunnel:



The picture on the right above shows some chroma interference patterning as the video signal being fed to the monitor is colour. The monitor does not have chroma filters and the video frequency response is excellent, extending well above the 4.43MHz colour sub-carrier, making the patterning visible.



One reason the image above is included here, apart from it indicating the performance of the monitor, is that it relates to a very clever story on an episode of Time Tunnel (End of the World). The scenario here is that data known to be true predicts an event about to happen, in this case the end of the world. However, a time traveller from the future arrives and says it is wrong and they know for a fact that the event never happens.

In this story there is mining disaster & collapse at the local mine in 1910. Many miners are trapped underground. When the time travellers arrive they are astonished that nobody is bothering to go and dig the miners out or attempt to save them. They are told that it is pointless because (the townsfolk point to the bright light in the night sky) Halley's Comet is going to destroy the Earth shortly.

One of the time travellers visits the local Astrophysics Professor and double checks his calculations, as shown in the scene above. Much to his amazement all the calculations check out and he comes to exactly the same conclusion as the Professor, the comet will hit Earth, the calculations prove it beyond any doubt.

But the time traveller knows it doesn't happen. So he concludes that there must be some other factor (a gravitational force) that they can't see and don't know about (a dark body) that is altering the Comet's trajectory. So he sets up a primitive radiometer and proves to the Professor that there is a dark body there. Then the news spreads to the town and they go and save the miners.

The moral of the story is you can never be 100% sure about any predicted future event, there might be a missing piece of information relating to some factor which could completely change the outcome of what the data appears to solidly predict. In a sense this might be yet another manifestation of the uncertainty principle.

POWERING THE MONITOR:

The device below was built to power the monitor with the same 3 phase 120V 400Hz power that it would have been provided with on an aircraft.

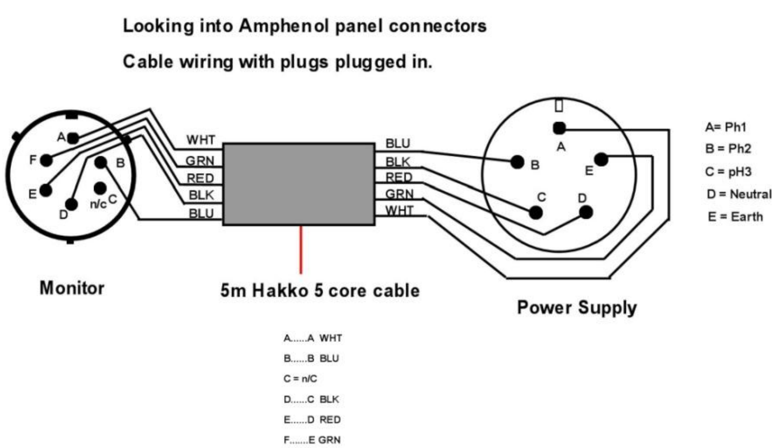
The power supply above is the topic of a separate article that can be found on the Worldphaco.com website.

Power Cable:

Since the monitor had no power cable supplied it was necessary to manufacture one. It requires a 5 core cable. I wanted to use a high quality silicone rubber covered heat resistant cable in keeping with the monitor quality, but finding a good 5 core cable of about 5 to 6 mm outer diameter (to suit the monitor’s Amphenol plug) at first was difficult. Then sitting at my bench I noticed that the Hakko soldering iron cable looked perfect on the outside, and on investigation it contained 5 cores. I was able to buy this in 5M lengths so I made up some power cables to connect the monitor to my newly built 400Hz three phase supply:

The diagram below represents the cable wiring. The 5 cores (which are Teflon covered) keep a uniform proximity to each other in the sheath, so looking at the two free ends, the array of colours in the clockwise or anticlockwise direction are reversed at each end. So to keep the wiring orderly in the plugs the colour sequence going around the plug pins is reversed in the 6 and 5 pin connector.

Also pin C is N/C at the monitor connector and pin F does not exist on the 5 pin connector.



UPDATE OCT. 2017.

I have discovered the probable source or origin of the basic circuit of the unique black level controller. It seems almost obvious now, as the kind of creative circuitry that it is, had “Tektronix” written all over it. I was pleased that my assessment of it, being a gated negative feedback loop, agrees with Tek’s description. They also describe it as the “deluxe” form of a diode clamp. Here is the documentation, 8 pages describing its operation, which I discovered hiding in a 1969 vintage Tek document:

FEEDBACK DC RESTORER CIRCUITS

from: Tektronix Circuit Concepts series.

Television Waveform Processing Circuits.

Gerald A. Eastman. First Edn, March 1969.

four-diode keyed clamp

The deluxe form of the two diode clamp circuits is the four-diode keyed clamp illustrated in Fig. 6-1. This circuit is mainly used for *measuring* rather than setting reference levels.

The circuit is inherently balanced since no center tap is used. Both the AC *and* the DC center-tap point is supplied by the second pair of diodes. The circuit gives rise to a great deal of circuit application versatility -- either as a normal DC restorer or a phase detector. When a pulse is applied to the primary of the transformer, a signal path is formed between point A and B.

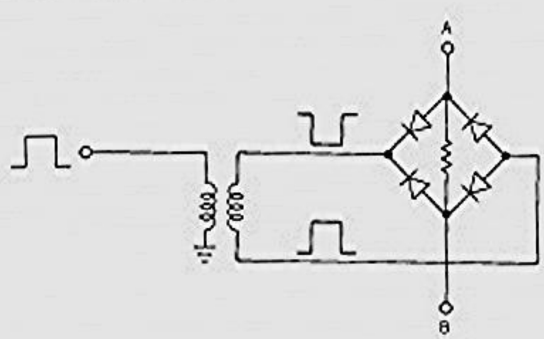


Fig. 6-1. Basic four-diode keyed gate.

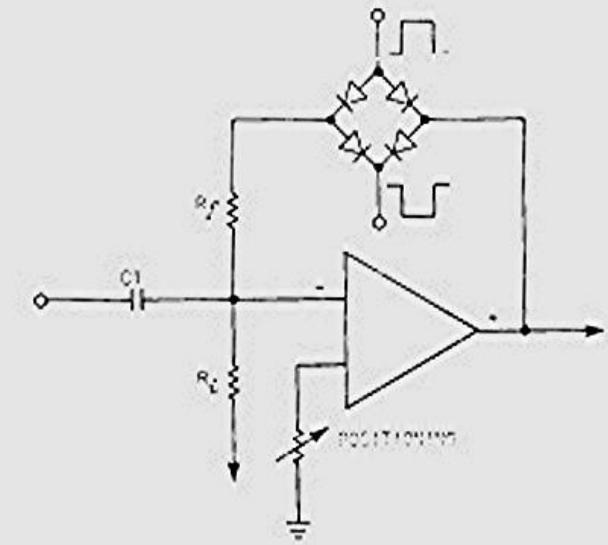


Fig. 6-2. Keyed feedback DC restorer.

keyed-feedback network

Fig. 6-2 shows one of the unique applications of the four-diode keyed clamp as a keyed-feedback network. The keyed-feedback network, when applied around an amplifier system, not only establishes a selected portion of the composite video waveform to a reference point, but also provides DC stability to the amplifier system -- eliminating the effects of amplifier drift.

The circuit (Fig. 6-3) has three basic parts:

1. A comparator to measure the difference between a fixed or variable reference voltage and the amplifier output voltage.
2. A diode gate to periodically close the feedback loop.
3. A memory circuit to "remember" the reference point between samples -- when the diode gate is open.

The circuit of Fig. 6-3 can be simplified still further for a preliminary illustration of the circuit principle.

gate timing

loop gain

Fig. 6-2 best illustrates the concept of the DC-feedback restorer. The pulses that close the feedback loop are arranged to occur when either the sync tip or back porch of the composite video waveform appears at the input. When the gate is closed, the loop gain of the amplifier system is essentially the ratio of R_f/R_i

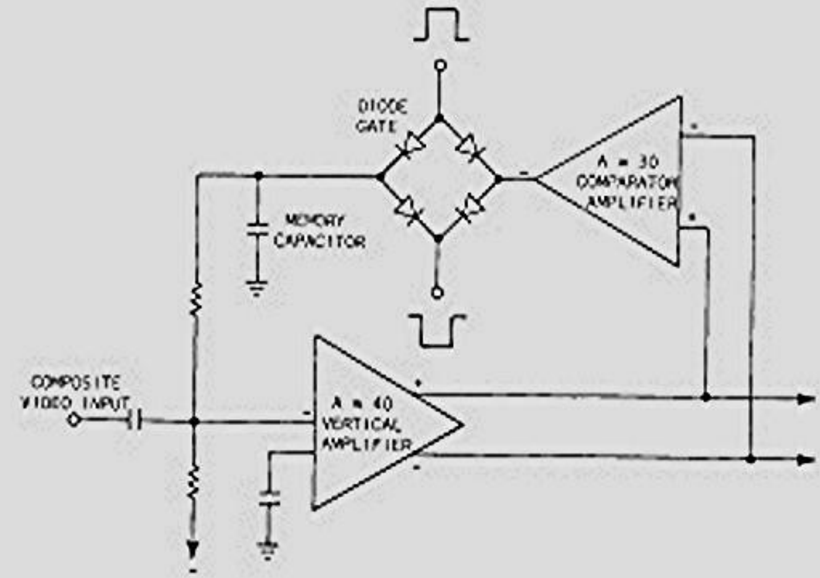


Fig. 6-3. Block diagram of an actual keyed DC feedback restorer.

-- in this case a closed-loop gain of about 1.6. A closed-loop gain of 1.6 is too good to be true, so closer examination of the circuit is necessary. Fig. 6-4 illustrates the equivalent circuit during feedback time. When the gate is closed for feedback purposes C1 is in parallel with R_i, so the loop gain of 1.6 exists only at, or very near DC. The result is a fast-operating feedback DC restorer with a low-pass filter in the feedback loop, having the equivalent effect on the overall amplifier system of a "slow" restorer. Putting it another way, insufficient feedback current is available to charge C1 to the correct value in one sample or less.

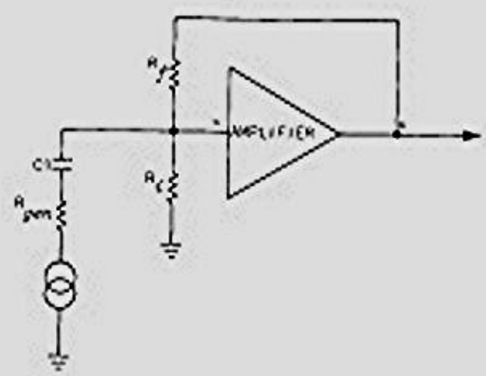


Fig. 6-4. Simplified block of feedback DC restorer - when diode gate is closed.

effective time constant

LF response

The second consideration is the low frequency 3-dB point "looking" into C1. The low frequency 3-dB point is, of course, determined by the RC network consisting of C1, R_i, and R_f. R_i and R_f *cannot* be considered in parallel, because the voltage on one end of R_f is moving in the opposite direction to the input signal. If R_i and R_f were considered in parallel, the time constant formed with C1 would appear to be 0.15 seconds corresponding to a 3-dB point of 1 Hz. However, R_f is part of the negative feedback loop, so the equivalent R_{f1} is approximately equal to $\frac{R_f}{A}$, where A is the open loop gain. The equivalent R_f in this case will be about 10 kΩ. Since the equivalent R_f is much smaller than R_i the time constant is essentially R_{f1} or about 1.0 ms, corresponding to a 3-dB point of about 150 Hz instead of 1 Hz.

Two important conclusions can be reached at this point when considering low-frequency abnormalities existing on the applied composite video waveform:

1. Under normal conditions, the field sync pulses will not be appreciably distorted but less hum will be displayed on the CRT than may actually exist.
2. The actual low-frequency 3-dB point will be affected by the loop gain of the amplifier system. When the GAIN control is turned to minimum the reduced system gain will *increase* the low-frequency response.

The third consideration is the dynamic voltage range of the feedback system. The dynamic range of the feedback amplifier is limited because the theoretical dynamic range is much larger than practical. For example, a 1.0-V change at the input would result in a 400-V change at the output (other end of R_f) if the dynamic range was unlimited and the system open-loop gain was 400.

Therefore, the practical dynamic range of the feedback amplifier is limited because:

1. A diode gate exists in the feedback circuit. The output voltage applied to the sampling gate cannot exceed the gating-pulse voltage amplitude.

2. The absolute voltage level of the sampled portion of the applied composite video is approximately at the same DC level each time the feed back gate is closed.

3. A large supply voltage for unlimited swing is not available or needed.

Fig. 6-5 illustrates the circuit details of the DC-feedback-restorer feedback-amplifier system. Since the DC-feedback restorer has two functions -- providing amplifier-system DC stability and establishing a selected portion of the composite video waveform to a reference point -- the circuit operation will be described in terms of the two separate conditions. The first condition is eliminating the effects of amplifier drift. Assume that pulses are applied to the diode bridge whether or not the composite video signal is applied to the amplifier input. Under ideal quiescent conditions, $+E_o$ should equal $-E_o$. If amplifier drift causes $+E_o$ to not equal $-E_o$, the difference voltage applied to

eliminate drift

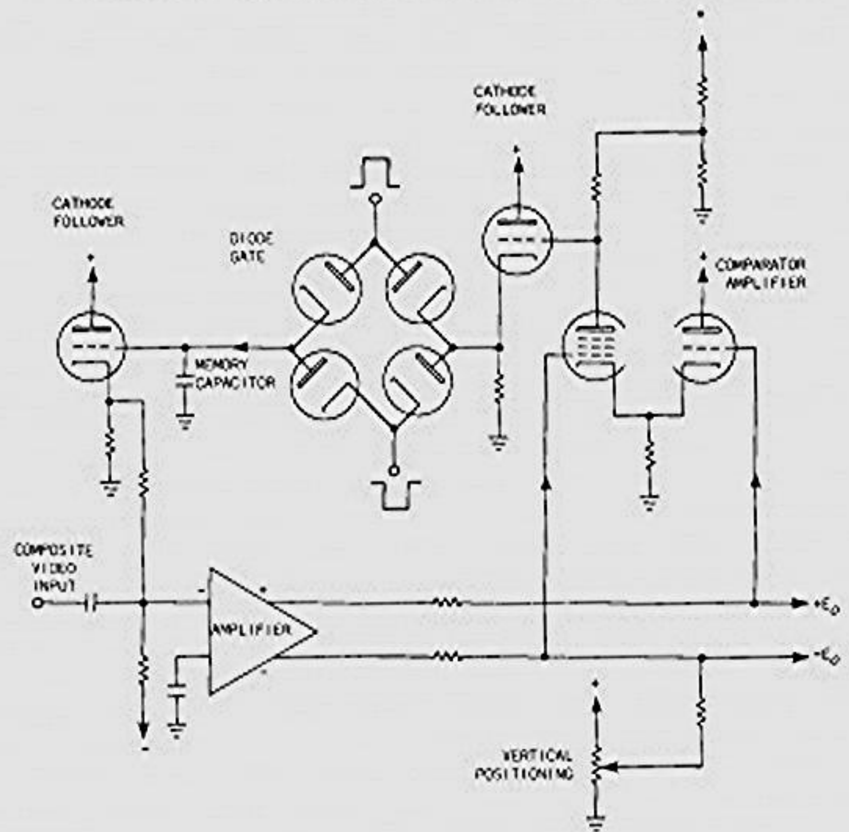


Fig. 6-5. DC feedback restorer.

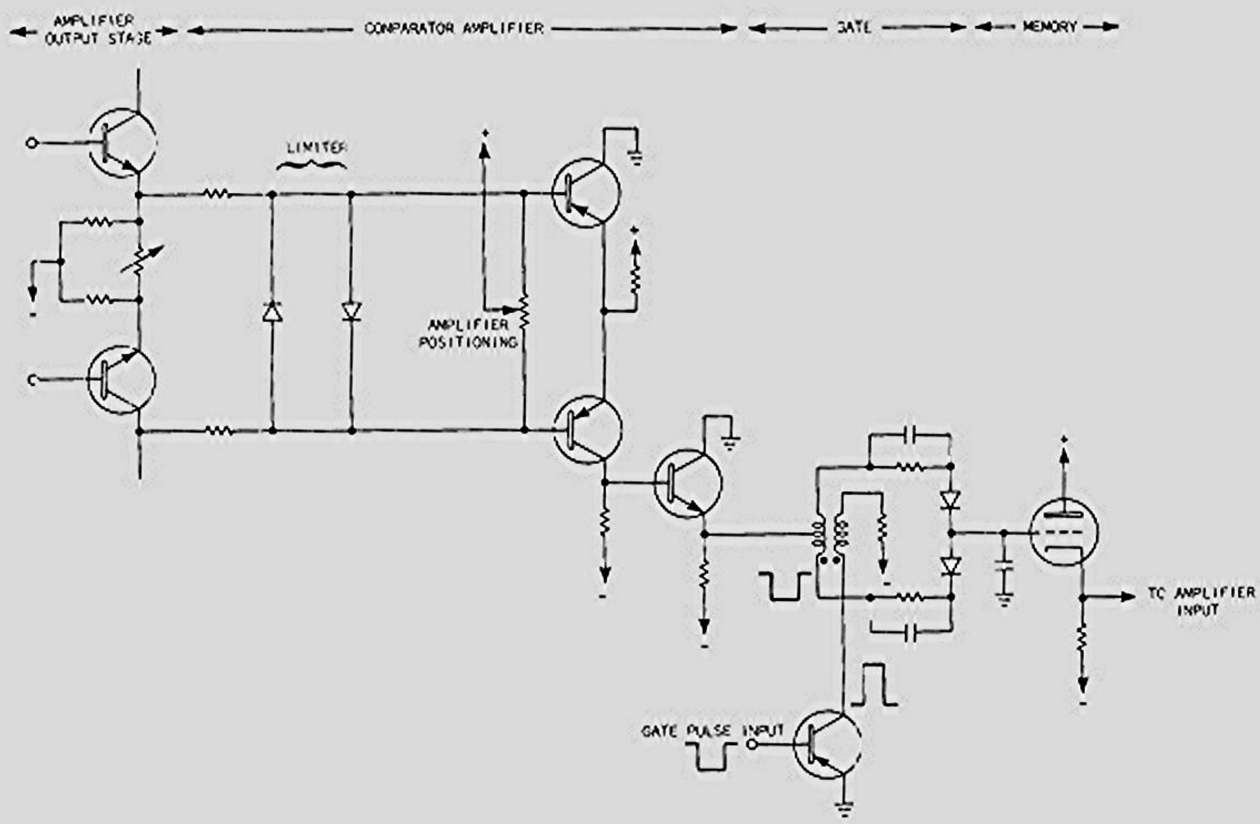


Fig. 6-6. DC-feedback restorer with dynamic-range limiting.

the differential amplifier (V1) will be amplified. The next pulse to close the diode gate will allow the amplified error voltage to charge the memory capacitor C2. Since the current available through the large value R_f is limited, C1 cannot be charged immediately to the correct voltage. However, the amplifier drift is normally a much longer time constant than the time required to charge C1 through R_f so the amplifier is virtually drift free.

reference level

sustained error signal

When a composite video waveform is applied to the amplifier input through C1, the second conditon now applies in addition to the first condition just described. The feedback diode gate is closed during a selected portion of the composite video waveform -- in this case the back porch -- and the absolute voltage level of the back porch is compared to the reference voltage at the center arm of the position control. Any difference voltage between the back porch DC level and the positioning control DC level is amplified and applied to the memory. Since C1 and R_f form a low-pass filter to the feedback error signal, the error must exist *continuously* for at least 1.0 millisecond -- the equivalent time constant of the low-pass filter -- before the error will be completely corrected. The time constant of the low-pass filter prevents complete removal of 60-Hz hum that may exist on the composite video waveform.

dynamic range limiting

low-Z drive

The circuitry shown in Fig. 6-6 is very similar to the circuit just described, with a few minor changes. Emphasis has been placed on minimizing the DC effects of color burst that may be present on the back porch of the sync pulse and reducing the effects of overdriving the comparator amplifier by off-screen signals. Since the dynamic range of the comparator amplifier is similar, two of the diodes are replaced with a center-tapped floating transformer winding. The composite video is applied push-pull from the amplifier output stage to the comparator amplifier. Back-to-back diodes in the base circuit of the comparator amplifier limit the dynamic range of the comparator of the feedback system to prevent overdriving the feedback system from unusually large signals. The output of the comparator is from an emitter follower to provide a low-impedance current source to drive the floating transformer winding. Since the feedback restorer is used in a vertical amplifier system, some form of positioning the CRT

display positioning

display is needed. The DC restorer is a gated negative feedback loop, so positioning can be easily accomplished by introducing an error signal into the comparator amplifier.

Notice in Fig. 6-6 that the necessary positioning is done by applying a differential current to the two inputs (bases) of the comparator amplifier.

With the limited dynamic range of the comparator amplifier, the feedback signal at the center tap of the transformer winding will not forward-bias the sampling diodes. A pulse applied to the primary of the transformer will produce large enough push-pull pulses on the secondary to forward bias the diodes; the pulse current, plus the DC current from the comparator emitter follower combined, then charge the memory capacitor.

8

So it is clear from these Vintage Tektronix documents that this idea is the basis for the black level stabilization in the Conrac monitor. As noted it stabilizes the DC position of the video signal, reduces amplifier drift and potentially removes some but not all hum modulation in the video signal.

Also, Tek used an equivalent circuit (fig 6-4) with the diode gate closed to help explain how it works, just as I had done in my description of the circuit.

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