TV and Monitor Deflection Systems

Version 1.21

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Table of Content

Introduction

Scope of This Document

TVs and most computer and video monitors depend on the use of similar (at least in concept) circuit configurations to generate several outputs:

Current waveform required in the deflection yoke coils of the CRT for linear sweep of the electron beam to create a high quality (geometry and linearity) picture. This is close to a sawtooth but not quite.

CRT High voltage (20 to 30 KV or more) required to accelerate the electron beam and provide high brightness and sharp focus, as well as other related voltages - focus and screen (G2).

Various auxiliary power and signals for other subsystems of the equipment (low voltage, CRT filament, feedback, etc.).

This document addresses the basic principles of operation of these types of deflection systems. While most people with any familiarity with TV or monitor operation or repair have some vague idea of how these circuits work (probably just enough to be dangerous), many are incorrect or at least very incomplete.

Most of this information applies to the horizontal deflection which operates at the higher frequency in a raster scan display (except for peculiar rotated portrait formats where the functions of the horizontal and vertical scan are interchanged. Equipment which utilizes this circuitry includes TV (direct view as well 3-CRT and light valve projection types), computer and video monitors, tube based video cameras (e.g., vidicon), and other magnetically deflected CRT devices.

Vertical deflection circuits are much less complex due to the lower scan rate (e.g., 50 to 120 Hz V as compared to 15.734 KHz H for an NTSC TV or up to 120 KHz or more for a high resolution computer monitor). Most of the control and output drive circuitry is contained in a special vertical chip in modern equipment.

Deflection System Safety

The deflection components of an operating TV or monitor contains substantial power with high voltages and high currents. This circuitry in many TVs and some monitors is directly line connected (no isolation). There are often large high voltage filter capacitors on the B+ supply and these may retain a lethal charge for some time after the plug is pulled. The CRT HV capacitance can also retain a dangerous charge - possibly for weeks!

Read, understand, and follow the recommendations in the document: Safety Guidelines for High Voltage and/or Line Powered Equipment before attempting any TV or monitor repairs. See the specific documents: Notes on the Troubleshooting and Repair of Television Sets or Notes on the Troubleshooting and Repair of Computer and Video Monitors as appropriate for your equipment.

Horizontal Deflection System Fundamentals

How Does the Horizontal Deflection Circuit Work?

Although there are many variations, the basic operation of the horizontal deflection/high voltage power supplies in most TVs, monitors, and other CRT displays is very similar.

For understanding the working of the deflection circuit regard the flyback transformer as an inductor. The airgap stores energy, some of which may be tapped off during flyback by secondary rectifiers (e.g., vertical deflection, signal circuits, and high voltage supplies) and non-rectified loads (e.g., filament supply) but these have hardly any influence on the basic working principles.

The scenario described below is only true in the steady state - the first few scans are different because the picture tube capacitance is still discharged. This represents a short-circuit at the secondary side of the flyback. It prevents proper demagnetizing, hence the core will go into saturation (unless special soft-start measures have been taken, like a B+ supply that comes up slowly). Generally, a hard start of the line deflection circuit represents a very heavy load on the HOT. This will happen after a picture tube flashover or if the B+ is connected suddenly (due to intermittent contact) and can mean instant death to the HOT due to secondary breakdown. See the section: More on HOT Failure.

Basic Deflection Circuit Operation

The following description is only the basics. For more information, see the article by David Sharples in "Electronics World", June 1996.

A very simplified circuit is shown below - many components needed to create a practical design have been omitted for clarity. First concentrate only on the portion of the schematic shown below to the left of the yoke components:

```
                     B+
                      o
                      |
                      +
                       )::
            Part of T2 )::
               Flyback )::
               Primary )::
                       )::
                      +
                      |
                      +-------+---------+----------+
                      |       |         |          |
     Horizontal       |       |         |          +
       Drive          | C     |         |           )::    (Horizontal
         T1       B |/      __|__      _|_          ):: L2  Deflection
     --+    +-------|       _/_\_      ---          )::     Yoke - HDY)
Driver  )::(        |\        |   D1    | C1       +
Stage   )::(     Q1   | E     | Damper  | Snubber _|_ C2
(not    )::(     HOT  |       |         |         --- S-correction
 shown  )::(          |       |         |          |
     --+    +---------+---+---+---------+----------+
                         _|_
                          -
```

B+ Return (may not be signal ground)

The current in the flyback primary and collector of the HOT are not equal. The horizontal deflection yoke, damper diode, HOT collector, snubber HV capacitor(s), and flyback primary all connect to the same point. We begin our adventure at the end of the scan - retrace – when the flyback period begins:

3. At the end of scan, current is flowing through the flyback primary to the HOT, Q1. At the start of the flyback period, Q1 turns off.

   (This must be done in a controlled manner - not just a hard shutoff to minimize stresses on the HOT - but that is another story). Since current in an inductor (the primary of the flyback has inductance) cannot change instantaneously, the current is diverted into the snubber capacitor, C1. The inductance of the flyback primary (T2) and C1 forms a resonant circuit so that the voltage climbs on C1 as the current goes down. At its peak, this voltage will be 1000 V to 1500 V.

4. C1 now begins to discharge in reverse through the primary of T2 (back into the B+ supply - the filter capacitor will stabilize the B+ output) until its voltage (also C-E of the HOT) reaches 0.

5. If there were no damper diode (D1), this voltage would go negative and continue to oscillate as a damped sinusoid due to the resonant circuit formed by T2 and C1 (and the other components). However, D1 turns on as the voltage goes negative and diverts the current through it clamping the voltage near 0 (-Vf for the diode).

Note that the damper diode D1 may have been built into the HOT T2 in the case of an inexpensive or small screen TV or even some monitors that don't have any circuitry for E/W correction.

Steps (1) to (3) have accomplished the flyback function of quickly and cleanly reversing the current in T2 (and, as we will see, the deflection yoke as well). The full flyback (and yoke current) are now flowing through the forward biased damper diode, D1.

6. **At the beginning of scan, the damper diode (forward biased) carries the bulk of the current from the yoke and flyback. The nearly constant voltage of the B+ across T2 results in a linear ramp of current now through the damper diode since it is still negative and decreasing in magnitude.**

7. **At approximately mid-scan, the current passes through zero and changes polarity from minus to plus. As it does so, the damper diode cuts off and the HOT picks up the current (with a voltage drop of +VCEsat). Current is now flowing out of the B+ supply.**

   The base-drive to the HOT must have been switched on before this point! Timing is not very critical as long as it happens between the end of the flyback and the zero crossing of the summed current. The location of the zero crossing depends on the secondary load, notably the beam current. Larger beam current requires that the HOT be switched on earlier. The designer has to do some optimizing here...

8. **During the second half of the scan, the HOT current ramps up approximately linearly. This is again due to the nearly constant voltage of B+ across the inductance of the flyback primary.**

9. **Near the end of scan, the HOT turns off and the cycle repeats.**

The HOT has a storage time between 3 us and 7 us, thus the base-drive is switched off earlier, in a controlled way to properly remove the charge carriers from the collector region in the HOT. The peak amplitude of the base current and the way it is decreased determine the ultimate dissipation in the HOT and are thus subject of heavy optimization. This is hampered by the fact that there is much spread in HOT parameters. Thus, the current in the flyback (ignoring the yoke components) is a nearly perfect sawtooth. The ramp portion is quite linear due to the essentially constant B+ across the flyback primary inductance. The current waveform can be easily viewed on an oscilloscope with a high frequency current probe. See the section: Probing TV and Monitor Yoke Signals.

The voltage across the C-E of the HOT is a half sinusoid pulse during the flyback (scan retrace) period and close to zero at all other times (-Vf of the damper diode during the first half of scan; +VCEsat for the HOT during second half of scan).

Caution: Without a proper high frequency high voltage probe, it is not possible or safe to observe this point on an oscilloscope with full B+.

However, where the equipment can be run on a Variac, this clean pulse waveform can be observed at very reduced B+. Excessive ringing or other corruption would indicate a problem in the flyback, yoke, or elsewhere.

Normally you would use a 100:1 probe suitable for 2 kV peak. You could always make your own voltage divider out of a couple of suitable resistors and use a regular 10:1 or 1:1 probe. Beware that also the capacitive division ratio must be correct because the line frequency is high enough to make it relevant.

The current through Q1+D1 is several amperes peak-peak. There's a lot of power circulating here, making this a dangerous circuit in every way!

The Deflection Yoke Connection

So, you ask: "Why can't the yoke just be placed in series or parallel with the flyback primary?". After all, the current is a nice sawtooth. Isn't that what we want?

There are several reasons including:

The desired yoke current is not quite a sawtooth but includes two major corrections: S and E/W (described below). These cannot be applied easily with such a configuration.

The flyback also generates the HV and secondary output voltages and the primary current might then be affected by these and change as a function of beam current (picture brightness) or audio level (although feeding the audio amplifiers from LOT windings is not common anymore).

Note that some TVs and monitors cut off power to the horizontal deflection circuits if the yoke connector is removed. This is a separate interlock and not a result of the B+ flowing through the yoke. Its purpose is to protect the circuitry and the CRT. With no deflection, the very bright spot in the center of the screen would quickly turn into a very dark permanent unsightly blemish. With appropriate precautions to avoid this costly situation, it is possible to power a monitor or TV with the yoke winding(s) disconnected to determine if a defective yoke is messing up the deflection system operation. See the documents: Notes on the Troubleshooting and Repair of Computer and Video Monitors or Notes on the Troubleshooting and Repair of Television Sets for additional information.

The yoke is placed across the C-E of the HOT in series with a capacitor (S-correction) and other components which in effect form a variable power supply (analogous to the constant B+) which is used to compensate for the various problems of scanning a nearly flat screen.

What are S and E/W or N/S Correction?

These terms actually refer to the various corrections to deal with what is normally called scan linearity and pincushion distortion. Most larger

TVs and nearly all high quality monitors will have various user and internal controls to optimize the corrections for each scan rate (multiscan monitors). Because the screen of most CRTs is relatively flat (even those not advertized as flat) and the electron gun is relatively close, any picture tube will naturally have serious linearity problems and pincushion distortion if there were no corrections applied. Near the edges and corners of the screen the spot will move faster because the same angular speed translates to a larger linear speed. This is simple trigonometry.

S-Correction Circuit Operation

The first correction to apply, in both directions, is S-correction. By simply putting a capacitor in series with each coil, the sawtooth waveform is modified into a slightly sine-wave shape (the top and bottom are somewhat squashed). This reduces the scanning speed near the edges. Linearity over the two main axis should now be good. When we add in the yoke components (only the horizontal deflection coil and S-correction capacitor or S-cap are actually shown above) conditions are only slightly more complex:

First, consider what would happen if instead of the S-cap, the yoke were connected to B+ like the flyback. In this case, the total current would divide between the flyback primary and the yoke. It would still be a sawtooth as described above. Of course, component values would need to be changed to provide the proper resonant circuit behavior.

That's called 'tuning of the flyback capacitor', to achieve the proper duration of the flyback pulse, matching the blanking time of the video signal, and to achieve the proper peak flyback voltage, matching the Vces specification of the HOT with a reserve of about 20%. That's two conditions, requiring two degrees of design freedom. There are 3 freedoms: supply voltage, flyback capacitor and yoke inductance.

With the S-cap and yoke wired as shown above, the inductance of the yoke and S-cap form a low pass filter such that voltage on the S-cap will be a smoothed version of the pulses on the HOT collector (similar in effect to the B+ feeding the flyback but not a constant value). The average value of the S-cap voltage will be positive. The S-capacitor together with the yoke inductance forms a resonant circuit whose frequency is tuned lower than the line frequency. It has the effect of modifying the sawtooth current into a sine-wave shape. This is called 'S-correction'. It reduces the scanning speed at the left and right edges of the screen.

The value of the S-cap can be selected so that the voltage varies in such a way as to squash the current sawtooth by the appropriate amount to largely compensate for the fact that the electron beam scans a greater distance with respect to deflection angle near the edges of the screen.

Think of it this way: When the scan begins, the yoke current is at the maximum value in the direction to charge the S-cap. The voltage across the S-cap is causing the current to decrease but the S-cap is also gaining charge so the rate of decrease is increasing. At the time the current passes through 0, the S-cap is charged to its maximum. The current now reverses direction retracing its steps. Got that! :-). This is another example of a portion of a resonant circuit. The voltage on the S-cap is varying by just the right amount to compensate for the geometry error.

For multiscan monitors, S-caps must be selected for each scan range since the timing varies with scan rate. These are only approximate corrections but good enough for most purposes. MOSFET or relay circuits take care that for each range of scanning frequencies the correct combination of S-correction capacitors is selected.

As an example, consider a multiscan monitor which supports VGA (31.4 KHz, 800x600 at 56 Kz (35 KHz), and 800x600 at 60 Hz (38 KHz):

For good geometry between 31, 35 and 38 kHz, two discrete values for the S-cap is barely enough. Actually a 3rd value optimized for 35 kHz would be better. If there is only one S-cap and it is optimized for 38 kHz, then at 31 kHz you will be using a too large angle of the sine (of the resonant frequency between the S-cap C and the deflection coil inductance). Possibly even > 180 degrees, making the current fold back. Apart from an obvious geometric distortion, there is also increased risk of HOT failure because you're operating too close to the resonant frequency.

N/S and E/W Correction Circuit Operation

Then remain the N/S and E/W errors, meaning that near the corners the scanning speed is still too large. To a large extent the N/S errors can be corrected by a suitable yoke coil design. For smaller tubes (90 to 100 degrees types) this is also possible for E/W errors. For larger tubes (110 degrees) or high quality tubes, electronic E/W correction is required. This is the well-known pincushion.

E/W correction is modulation (which implies multiplication) as a function of vertical beam position. The amplitude of the horizontal deflection current is modulated with a parabola waveform which is derived from the vertical deflection circuit. This squeezes the top and bottom lines back into the left and right screen borders.

N/S correction (if any) is a method of injection - addition of a high frequency waveform (harmonics of the line frequency) to the low-frequency field-deflection waveform.

This requires costly nasty circuitry which is better avoided. This is how the diode modulator for E/W correction works:

```
           B+
            o
            | (Vb)
            +
             )::
  Part of T2 )::
     Flyback )::
     Primary )::
             )::
            +
            |                    <- Yoke components ->
            +-------+---------+---------+----------+
            |       |         |         |          |
            |       |         |         |          +
            |       |         |         |           )::    (Horizontal
            |     __|__      _|_        |           ):: L2  Deflection
            |     _/_\_      ---        |           )::     Yoke - HDY)
            |       |   D1    | C1      |          +
            |       | Damper  | Snubber |         _|_ C2
            |       |         |         |         --- S-correction
            |       |         |         |          |
            |       +---------+---------)----------+
            |       |         |         |(NC)      |
            |       |         |         |          +
            | C     |         |         |        L3 )::
        B |/      __|__      _|_       _|_   Bridge )::  L4
     -----|       _/_\_      ---       ---     coil )::  E/W Coil
          |\       |   D2    | C3      | C4       +     ::::         (Vm)
       Q1   | E     | Damper  | Snubber | Snubber  +----+^^^^+---+-----+-----
       HOT  |       |         |         |          |             |     |
            |       |         |         |      C5 _|_          +_|_   E \|B
            |       |         |         |  Bridge ---        C6 ---  Q2  |---
            |       |         |         |     cap  |             |    C /|
            |       |         |         |          |             |     |
            +-------+---------+---------+----------+-------------+-----+------
           _|_                                            E/W Amplifier (PNP)
            -
       B+ Return (may not be signal ground)
```

The deflection supply B+ gives a constant voltage Vb. At the output of the E/W amplifier there is a variable voltage Vm. Because there can not be an average voltage over any coil, the average voltage over the deflection circuit (L2 + C2) is Vb-Vm. The scanning width is proportional with this voltage Vb-Vm. By modulating Vm as a field-frequency parabola which is higher for the top and bottom lines it is achieved that the scanning width is reduced for the corners of the screen.

The required field-parabola waveform is derived from the field deflection circuit. Amplitude and DC-level are adjustable, for correcting pin-cushion distortion and setting the screen width. EHT is not influenced !

The E/W amplifier usually has a PNP emitter follower only, because it must only sink current and dissipate a bit of power. The coils L3 and L4 take care that the E/W amplifier sees no line-frequency. The "bridge" components L3 and C5 resemble the deflection coil with its S-correction capacitor and carry the large amplitude alternating current. L3+C5 are tuned to approximately the same frequency as L2+C2. C1, C3 and C4 must be tuned so that EHT is independent of Vm and peak voltage over D2+C2 is high enough but not too high when Q2 is off. C4 is usually a small ceramic capacitor of approx. 1 nF mounted close to the HOT Q1, it also suppresses EMI. Flyback capacitors are critical components. Wrong types may overheat and burn. Bad contacts here or elsewhere in the deflection circuit may arc and also cause fire.

There are many variants to this circuit, e.g. for dynamic S-correction. Multi-sync monitors need added circuitry to make the EHT independent of the line frequency (if there is not a separate EHT supply, that is). If the E/W modulator fails then you will see that the top and bottom lines will be much too wide. There are several parts that could have failed. It's usually not too difficult to find why there's no parabola. If you have partial loss of E/W modulation, notably in the extreme corners, then you should suspect the tuning of the 3 flyback capacitors that belong to the diode modulator circuit. That's a specialist job...

S-Correction Problems

An open S-cap will result in no horizontal deflection - a vertical line.

A shorted S-cap will likely load down the B+ possibly resulting in a blown fuse or other power supply components.

An S-cap that changed value (or in the case of a multiscan monitor, selected to be the wrong value) will result in distortion at the left and right sides of the screen:

> Too low: picture will be squashed towards edges.
> Too high: picture will be stretched towards edges.

Note that this is not the same as what is commonly called linearity which would likely affect only one side or gradually change across the screen.

Horizontal Linearity Correction

Since there is non-zero resistance associated with the components (mainly coil losses) in the yoke circuit (yoke winding, ESR of S-cap, etc.) the world is not quite as ideal as one would hope. Without compensation, this resistance would result in non-linearity of the picture - it would tend to be squashed on the right side as the resistance saps energy from the yoke circuit.

The waveform becomes a damped sinewave, which will be 'undamped' by restoring energy during the flyback. One way to deal with this is to add a magnetically biased saturable inductor in series with the horizontal deflection yoke. This is called the linearity coil.

Its core is magnetically biased near the point of saturation such that the inductance decreases with increasing current and this helps to stretch the right hand side of the scan. In other words, during the scan the coil saturates so that the inductance decreases. At the end of scan there is practically no voltage left over the linearity coil so that the deflection coil gets maximum voltage.

E/W Correction Problems

The common name for the adjustments is likely to be 'Pincushion Amp' and 'Pincushion Phase'. They are controlling the E/W correction circuits.

Pincushion Amp adjusts the amplitude of the correction signal. Pincushion Phase adjusts where the correction is applied on the vertical scan.

- **Failure of the E/W correction circuit will result in very noticeable pincushioning distortion of the vertical edges.**
- **Excessive E/W correction will result in barrel distortion of the vertical edges.**
- **A bad power supply derived from the flyback could also result in similar symptoms due to ripple or lack of power to the pincushion circuitry.**

Differences Between N/S and E/W Correction Implementation

While the desired effects are symmetric - modulate the amplitude of one component of the deflection circuit (H or V) by the other (V or H), the implementations will differ substantially. The reasons should be obvious: The line frequency is much higher than the field frequency.

E/W correction is easy: the lower frequency modulates the higher frequency. This reduces to simple amplitude modulation. Well, simple in principle. The line circuit is a high-energy circuit. For this purpose the diode modulator circuit has been invented. It allows an energy exchange between the line deflection circuit and a pseudo deflection circuit.

N/S correction is difficult: the higher frequency modulates the lower frequency. It can be done with sort-of amplitude modulation by using

a 'transductor'. This is not a transformer but a component with 2 coils and a saturable core where the (line frequency) current through 1 coil modulates the inductance of the other coil. If there are tuned parts in the circuit then the correction will be highly sensitive to line frequency variations.

It can also be done with a regular transformer, by injecting a strong signal (from an amplifier) with line frequency components into the field deflection circuit.

Either way, it's an expensive solution which should be avoided by designing the deflection coils in such a way that the picture tube needs no active N/S correction.

Several types of auxiliary power may be obtained from the flyback, somewhat as a byproduct of the deflections system operation. These may provide DC (using high speed rectifiers and small filter capacitors), or AC. Although not always well known, the coupling factor with the primary is decent for a flyback transformer and so there can be scan rectifiers as well as flyback rectifiers in the same system - and often are. Refer to the diagram, below:

- Scan power is obtained during the forward stroke as with a normal' transformer. Energy is transferred while the HOT/damper diode is conducting. The output rectifier is oriented so that current flows during scan time. (Dots on the transformer winding match.)
- The scan rectifiers make no use of the stored magnetic energy, they load the primary directly during the scan part. They do not cause an increase of the stored magnetic energy so a heavy load is not a problem.
- Flyback power is obtained from the stored energy in the flyback transformer's inductance when the HOT shuts off. The output rectifier is oriented so that current flows at flyback time. (Dots on the transformer windings oppose.)
- The flyback rectifiers on the other hand (especially the EHT) draw from the stored magnetic energy. When the secondary load increases, the magnetization current will also increase. Ultimately this will cause saturation of the ferrite core. Excess beam current is a common cause for this and should be avoided by the beam current limiter. The advantage of a flyback rectifier is that it provides 7 times more volts per winding than a scan rectifier.
- AC power (usually only for the filament or a feedback signal) flows during both scan and flyback.

```
                 _  _
                  \/                                   _/\_
   B+ ------+    +----|>|-----+---o +V1  B+ ------+    +----|>|-----+---o +HV
           o )::( o  Scan     |                  o )::(   Flyback   |
             )::(  Rectifier _|_+                  )::(  Rectifier _|_+
             )::(            ---                   )::(            ---
             )::(             |                    )::(             |
       _/\_  )::(             |              _/\_  )::( o           |
  HOT ------+    +------------+         HOT ------+    +------------+
                             _|_                                   _|_
                              -                                     -
```

Here, V1 is just a typical example of an auxiliary supply derived from a scan rectifier and HV is the best known example of the use of a flyback rectifier. Since the deflection system runs at 15 KHz or higher, fast recovery diodes must be used as rectifiers. However, at these frequencies, the uF ratings of the filter capacitors can be quite small compared to power line (50/60 Hz) based systems.

EHT (High Voltage) Generation

The EHT (Extra High Tension or HV to the CRT) is generated from a secondary winding on the flyback transformer having several thousand turns of very fine wire. Being a flyback supply, the actual output voltage is many times what would be calculated based on turns ratios alone. The HV rectifier consists of a stack of silicon diodes with a total PIV rating of 50 KV or more.

Because the flyback pulse is so narrow, the rectifier diode will conduct only a short time. Thus the peak current in the winding will be quite high, resulting in a significant voltage drop when loaded. The internal impedance of the EHT source is in the order of 1 MOhm, so with a load of e.g. 1 mA the EHT will drop 1000 V = -3%. Usually the EHT voltage is far from stable, 10% drop is quite normal.

If the EHT voltage drops, then the electrons will be accelerated less and will move through the deflection field at a lower velocity. As a result they will be easier to deflect by the magnetic field, and the picture size will grow. Without special measures, brighter pictures will be larger. The measure is to feed some EHT information or beam current information to the deflection circuits, reducing the deflection current amplitude a bit for bright pictures. For horizontal deflection this is done by the E/W modulator. This is called anti-breathing.

Sets with raster correction free picture tubes don’t have an E/W modulator. There the correction may be done by means of a power resistor in series with the B+ supply. A large beam current causes more power consumption, this lowers the B+ supply voltage and thus reduces the line deflection current. That also reduces the EHT even further, but the deflection current has a stronger effect on the picture width than the EHT. Better methods exist too.

The EHT information is also used to protect the flyback transformer from overload. As the load increases, the average primary current rises. Ultimately it may reach a level where the transformer core may go into saturation. This causes large peak currents in the HOT which might lead to destruction. To prevent this, some EHT information is fed to the contrast controller, to automatically reduce the picture brightness whenever the white content is too much. This is called the average beam current limiter.

A failure in the video path, like a video output amplifier stuck at 0 V, causes a high beam current that will not react to the contrast controller. In that case the beam current limiter will not work and the set should switch off automatically, usually within a few seconds after applying power. When the cathodes heat up, you’ll see an even picture with diagonal retrace lines and then it will switch off.

The Difference Between the Ideal and the Real

Don’t expect to find the circuits shown above staring you in the face when you get your Sams’ Photofact or service manual. There are a semi-infinite number of variations on this basic theme. Some of them will, to put it mildly, appear quite obscure (or to put it more positively, creative) at first.

You may see all sorts of additional passive components as well as transformers for generating additional voltages not provided by the flyback. There may be diodes in places you would think

would be impossible. Therefore, to really understand even approximately how each design works may require some head scratching but the basic operation of them all seems to be very similar.

Horizontal Output Transistor (HOT) Information

Why are There So Many Different HOTs?

I find it fascinating (ok, well at least interesting) that after 20 years of designing totally solid state TVs and monitors, HOTs have not become jelly bean parts. Why does every new design insist on a unique HOT? I don’t believe this is simply due to increased requirements like wider deflection angles or (for computer monitors) higher scan rates.

Actually there is still some progress going on :-).

TV’s for Europe DO get higher scan rates, you know. Our entire high-end range runs on 31250 Hz. Sets with VGA capability often run even higher. 100 Hz HDTV was supposed to run on 62500 Hz but that is a big technological problem as you might imagine.

Larger screen sizes (32” 16:9, 33” 4:3) do tend to have less sensitive deflection coils, so the peak-peak amps go up. Combined with the higher scan rate this often means that some new transistor must be found, even if it is only a higher rated selection from an existing type. There is also 1700 V Vce types next to the regular 1500 V.

And in USA it is known that setmakers (like ourselves) have standard transistors marked with a different type number, to prevent repairmen from putting in just any would-be replacement type. For a fact, it IS risky to put in the wrong replacement, the faulty drive conditions may destroy it early. So try and avoid this.

To comfort you, the BU508 is still widely used!

HOT Specs and Substitution

Refer the article on deflection circuit design by David Sharples (Electronics World & Wireless World, June 1996).

Every line transistor has its own requirements for:

> **Amount of base drive current, especially the Ib at end-of-scan. Waveform of base drive current (rising, steady, falling) Speed of reduction base drive current at switch-off.**

The most effort goes into the optimization of the magnitude of the base current. The problem is: gain spread. There used to be other spread factors influencing the dynamic transistor parameters but

these have been mostly eliminated by better process control at P.S.. You have to find one optimum drive so that neither the high-gain nor the low-gain type will dissipate too much.

Overdriving causes a slow switch-off behavior, some collector current keeps flowing during the beginning of the flyback and will cause dissipation.

Underdriving causes bad saturation, the collector voltage will start to rise before the flyback should start. This too causes dissipation. Either condition is easily observed with an oscilloscope, a current probe and a 1:100 voltage probe (be sure to calibrate it for HF !).

The dissipation as a function of the base drive current is a more-or-less parabolic function with a global minimum. The minimum will be different for high-gain and low-gain types. By measuring the curves for both extreme types and combining them, an optimum drive for the random type will be found, with a figure for the worst-case dissipation.

All this will only be true if you insert a device which is a member of the population spread for which you optimized the base drive. If you just insert a random other device (different type, same type but different brand, same type and brand but much older/newer batch) then all bets are off. Dissipation may be way too high, with early failure as a result (and possibly a distorted picture geometry due to excess damping of the waveform).

It is certainly not possible to substitute a standard HOT (BU508) in place of a more advanced type (in >> 15 kHz applications like monitor). It is also a very bad idea to substitute a BU508 in place of a much lighter type like a BUT11 (used in <= 17” sets). It will fail!

With horizontal output transistors, it is not true that ‘bigger is better’. If you substitute a heavier transistor (more amps, more volts, more watts, faster switching, whatever) for a lighter one, then there is a very big chance that it will fail earlier, not later. The reason is that the drive conditions will now be wrong (most likely underdrive) and the transistor will overheat from too high conduction losses (Ic * Vce,sat). So do yourselves a favour and get a correct replacement type.

Is there a Universal HOT Replacement for TVs?

WARNING: As noted elsewhere in this document, the following approach is much less likely to work with long term (or even more than a few millisecond) reliability in high performance computer monitors.

(From: Chris Jardine (cjardine@wctc.net)).

I shouldn’t say this, but, the TV repair shop I worked for a number of years ago stocked 1 universal Horizontal Output Transistor 2SC1308K or NTE238. This worked in almost every set out there that used a transistor and not SCR’s (RCA, etc.). This may not be the best way of substituting, but, these 2 part numbers seem to have fairly high gain, power capability, voltage ratings, current ratings, etc. These characteristics made it a good substitute and when you buy 100 at a time you would get a really good price.

This may not work in your case, but, my $.02

Is There a Universal HOT Replacement for Monitors?

"Would anyone like to comment on BU508's, they should be to the same spec. and born equal. My experience has been that different manufacturers BU508's behave differently. One make will fry and last about 3 weeks, put in a different make, no circuit change, and it runs cool, and is still running 3 years later. Price doesn't seem to be a guide, a $1 one may run cool and have no mfr. code, while a branded one might cost a lot more and run hot."

Yes, here you have the problem exactly!

There is such a thing as component spread. Base drive must be optimized for the whole range of gain within a type. That range can be so large that at the limits of the spread the dissipation can still be too large. The reason is that the device with the largest gain will be overdriven, causing a tail in the current at switch-off, whereas the device with the smallest gain will be underdriven, causing it not too saturate enough. Each condition can be easily viewed on the 'scope. By varying the base drive you can minimize dissipation.

Normally one basedrive is set for the entire population, accepting the variation in dissipation and its upper limit. Sometimes the variation is so large that this will not be acceptable. But this is unlikely for a BU508 in a 16 kHz application. Substituting it with a similar type from a different brand with different parameter spread may indeed cause it to dissipate too much and thus fail early. This has nothing to do withprice or quality, just with a different optimum base drive. If base drive has been optimized for a brand with low parameter spread then it can be that the heatsink may have correctly been selected smaller...

Since you live in the UK, you should definitely read David Sharples' article in Electronics World (was it June 1996 ?). He literally optimizes base drive for a living.

Typical Types of HOTs Used in Monitors

(From an engineer at Philips).

14", SVGA (38 kHz)	**A-types: BU2508AF, 2SC4830, 2SC5148.**
	D-types: BU2508DF, 2SC4762, 2SC4916, 2SC5149,2SC4291, 2SC5250.
15", XVGA (64 kHz)	**A-types: BU2520AF, BU2522AF, 2SC3885A, 2SC3886A,2SC4757, 2SC4758, 2SC5129, 2SC4438,2SC4770, 2SC4743, 2SC5067, 2SC5207, 2SC5251, 2SC5002.**
	D-types: BU2520DF, 2SC3892A, 2SC3893A, 2SC4531,2SC4763, 2SC4124, 2SC4769, 2SC5296,2SC4742, 2SC4744, 2SC4927, 2SC5003.

(A=no damper, D=built in damper diode).

For designs with larger screen sizes (and higher frequencies) the device selection is not so straightforward as some designs split the horizontal deflection and EHT stages.

In nearly all the above cases, the devices will plug-in substitute for each other within category. Continuous dissipation is hardly ever the cause of failure (never for Philips devices). Failure is usually due to some infrequent transient condition. For multi-frequency monitor designs 1991-1994 mode-change was/is a big killer. When repairs are made it is wise to cycle, through a mode-change sequence. Delays of about 1 min. between changes should be used, shorter delays can cook the device.

As a rule, once an engineer has a bad experience with mode change he takes greater care in the small-signal circuitry of his next design. This has led to mode change, in general, becoming more benign in the last couple of years. However, in Taiwan & Korea there is a high turn round of engineering staff and some, shall we say, less than perfect designs do still reach production.

To “cook” a device by mode changing would take at least 30 mins. of continuous changing with a delay of about 20 seconds between each change.

If a device fails during such a sequence the old spit test is good indicator of why a device fails. That is, a drop of spit on the HOT immediately after failure can tell us a lot: if it sizzles, then the device has probably cooked, if it doesn’t then the device failed instantly after one stressful cycle. Frontiers of technology it is isn’t but it is a useful technique. If you do get fails which haven’t been caused by the HOT “cooking” I have no easy solution, sorry !

Winfield Hill’s comments reflect the experiences of many. School physics teaches that bipolar’s are current driven and MOSFET’s are voltage driven. In practice, of course, this is a gross over-simplification. A MOSFET in deflection would, as we say in the north of England, have to be a “bloody big bugger”. For example, a 1500V MOSFET that behaved as a BU2508 would have to be nearly twice the size and at least twice the price. Getting 10V on all the gate cells of such a big chip requires a lot of charge to be injected (i.e., current) and then removed (reverse current); much like a bipolar drive.

Varieties of BU508 HOTs

(From: J. G. Simpson (ccjs@cse.bris.ac.uk)).

BU508 series seem to come in a number of variants, I haven’t sorted out the specification for each listed variant, but have found that it’s worth trying replacements by different manufacturers. Also if the device is on a grounded piece of metal as heatsink try adding another radiator (twisted vane is my preference). Some TV manufacturers introduce post production mods to change resistance values to provide more drive into the base, this may be in the base or emitter. Scope the waveform for parasitic high frequency oscillation and check that the waveform looks clean. Check voltage rails, supply and derived, and that the set is not over scanning. Check all the components around the horizontal output stage, it may be the manufacturer. had a duff batch of some component (often a capacitor that goes OC) that keeps failing which then stresses the BU508.

Why Do Apparently Similar or Better HOTs Sometimes Run Hot and Blow?

It is often surprising that replacing a horizontal output transistor with one that has overall better specifications does not work out - it may run hot and fail.

There is more to characterizing a transistor than just maximum voltage, current, and power dissipation.

One important parameter is current gain: Too low a gain for a particular operating point may result in incomplete turn-on during scan resulting in high dissipation. You want the transistor to be in the fully saturated state. A larger HOT is more likely to have a lower current gain.

If you read the app notes put out by the manufacturers like Motorola you will also find that fast turn off based drive (negative step) is actually not what you want since this traps excess carriers in the high resistivity collector region which leads to continued conduction and heating. The ideal waveform also provide adequate drive during scan but not excessive overdrive and is thus an increasing ramp to account for the increasing collector current during scan.

Characteristics like this are not dealt with by the basic specs but can differ substantially among otherwise similar transistors.

Also see the section: HOT Specs and Substitution.

Storage Time of HOTs

Storage time differs between transistor types, there’s parameter spread within a type (lower hFE gain gives shorter storage time and v.v.) and it depends on load (higher beam current or larger deflection amplitude due to E/W modulation gives shorter storage time).

Variations in storage time would translate into horizontal position errors of the picture. That’s why the base-drive to the HOT is generated by a PLL that measures the phase of the output of the HOT, which is the flyback pulse at the collector. This PLL is called the PHI-2. It keeps a constant phase relation between the sync at the input and the flyback pulse. As a result, you will see the base-drive pulse shifting in time as a function of HOT load, this is normal.

Most deflection processors generate a base-drive pulse with a constant duty-cycle. This means that also the switch-on moment of the HOT will vary with the load. This makes it extra difficult to optimize the base-drive because there is only a limited time interval where the HOT may be switched on and that interval is shorter with high beam current load. On-time is typically between 50% and 55%, depending on the IC.

The feedback of the flyback pulse to the PHI-2 PLL is not perfect because the shape of the pulse distorts as a function of beam current. This will give a dynamic geometry error. It is compensated by feeding a certain amount of EHT information to the PLL.

Typical HOT Dissipation

Just measuring the actual power dissipation in a HOT is not trivial due to the nasty shapes of the voltage and current waveforms.

FYI, David works with Philips Semiconductors in England. He has been an application engineer for many years, so he knows exactly what's going on in our business.

(From: David).

```
14-21", 16 KHz: About 1 W some have the HOT running in free-air)
21-36", 16 KHz: Less than 2 W  (some new large CRT's only need 9 A p-p)
25-36", 32 KHz: Less than 4 W  (dissipation really is prop. to frequency)
```

I am sure I don't need to tell you that the dissipation varies with the type of HOT used and the drive. Philips BU25xx family is of course the best in this respect but Toshiba & Sanyo are not that far behind.

Why MOSFETs are Not Generally Used for HOTs

One would think that with a MOSFET's high impedance voltage drive and other desirable characteristics, they would have displaced bipolar

transistors for horizontal deflection circuits. Why not?

True, a MOSFET is much much much easier to drive. In modern switched-mode power supplies they reign, rightfully so. They are effective and rugged. But in line deflection things are not so easy. I'll give you 4 reasons:

1. **The flyback pulse is regularly 1200 V peak, allowing for margins you need a 1500 V device. There are few or no FETs available for that. In a small set, a 1000 or 1200 V device may be usable. With effort, the deflection circuit impedance may be re-scaled for greater current and lower voltage.**

2. **The conduction losses (Vds = Id * Rds) of a FET are quite high, this not only is wasteful dissipation but it also affects the linearity of the picture (it's a damped sine-wave, going slower and slower).**

3. **For the same power losses a FET needs a much bigger silicon area, also FETs are made in a more advanced process, with IC-like features, this translates directly into greater cost! They are several times more expensive.**

4. **A FET has no storage time, hence it has no storage-time modulation, which is a disadvantage because that would help to improve the natural stability of the control of the phase of the line deflection.**

And these are just some major reasons, there are minors too. We have looked into it time and again and still the bipolar wins!

Optimizing Base Drive for HOTs

It is interesting that the problem of base drive optimization receives a fair bit of attention, either for allowing a (non-compatible) replacement HOT to survive or for rebuilding a fixed frequency monitor to a different scan frequency. I wish there was an easy way to teach the average hobbyist a method to do this himself.

The recipe itself isn't all to difficult: mostly we change the value of the power resistor that feeds the line drive circuit until the temperature of the HOT heatsink is at minimum. Too much basedrive current increases the switching losses, too little basedrive current increases the conduction losses. The optimum is somewhere in the middle. All you need is a handful of power resistors and a thermometer on the heatsink.

If you need to optimize for a general HOT type (as opposed to one single sample) then you kindly ask the manufacturer to provide some, limit case samples (lowest and highest hFE found) and find a basedrive that satisfies both extremes. Of course you must select a slightlylarger heatsink. So far so good. The difficult bit is when you find that you need to change other components in the drive circuit as well, like the spread inductance of the driver transformer, a damping resistor, a duty cycle of a drive signal etc. And of course you may find that the

HOT you planned to use is entirely unsuitable for this application ...

Anyway, it's never a case of just 'drive it hard'.

What is This Diode Across My HOT?

It is called a damper diode and is essential to proper operation of the TV's or monitor's horizontal deflection as well as to the continued life and happiness of the HOT. Using an HOT with an internal damper is OK even if there is a separate one in the circuit. The other way around (leaving it out entirely) will likely result in instant - i.e., single scan - destruction of the HOT. This is because in modern deflection system designs, the damper carries the horizontal yoke current for a significant portion of the scan. If it is not present, the HOT will be forced to try to eat this current - in reverse - across C-E.

The damper is a special high voltage fast recovery type of diode - a 1N400x type will not work in its place.

BTW, many of these HOTs have a D after the part number to indicate that they have the internal damper and include a B-E resistor (which may confuse transistor testing) of about 50 ohms. However, the D is not a sure indication of an internal damper - nor is its absence an indication of a lack thereof. The entire part number must be checked to be sure.

What is This Funny Capacitor (or Capacitors) Across My HOT?

These may go by the name flyback, high voltage, snubber, or deflection capacitors. When the HOT is shut off, the current flowing in the inductance of the flyback primary and horizontal deflection yoke cannot be stopped instantly. These capacitors provide a place for this current to go and is part of a tuned circuit (in combination with the flyback and yoke) which needed to accomplish the flyback function.

If this capacitor is open or missing, excessive flyback voltage will result probably killing the HOT. If the HOT does not fail, the result will likely be greatly increased high voltage. Should the X-ray protection circuitry not shut down the deflection, there could be internal or external arcing and/or destruction of components like the flyback or tripler.

For proper operation and continued safety, only proper exact replacements should be used for these parts.

Horizontal Output Transistor Failure and Testing

HOTs Keep Blowing (or Running Excessively Hot)

Unfortunately, these sorts of problems are often difficult to definitively diagnose and repair and will often involve expensive component swapping.

You have just replaced an obviously blown (shorted) horizontal output transistor (HOT) and an hour (or a minute) later the same symptoms appear. Or, you notice that the new HOT is hotter than expected:

Would the next logical step be a new flyback (LOPT)? Not necessarily.

If the set performed normally until it died, there are other possible causes. However, it could be the flyback failing under load or when it warms up. I would expect some warning though - like the picture shrinks for a few seconds before the poof.

Other possible causes:

1. **Improper drive to horizontal output transistor (HOT).**

   A too weak drive (or a HOT with a too low Hfe) causes Vce(sat) to be too large, giving conduction losses.

   A too strong drive (or a HOT with a too high Hfe) causes it to switch off too slowly, giving switching losses.

   Base drive should be optimized to balance between these 2 losses. Check driver and HOT base circuit components. Dried up capacitors, open resistors or chokes, bad connections, or a driver transformer with shorted windings can all affect drive waveforms.

2. **Excessive voltage on HOT collector - check low voltage regulator (and line voltage if this is a field repair), if any.**

3. **Defective safety/flyback capacitors or damper diode around HOT. (Though this usually results in instant destruction with little heating).**

4. **New transistor not mounted properly to heat sink - probably needs mica washer and heat sink compound.**

5. **Replacement transistor not correct or inferior cross reference. Sometimes, the horizontal deflection is designed based on the quirks of a particular transistor. Substitutes may not work reliably.**

   Well, you can always try to optimize the base drive by changing the value of the power resistor that feeds the drive circuit at the primary of the drive transformer. But you’re on your own here! Clearly label what you have done or else your name will be mud if the unit ever needs to be repaired by someone else in the future.

The HOT should not run hot if properly mounted to the heat sink (using heatsink compound). It should not be too hot to touch (CAREFUL - don’t touch with power on - it is at over a hundred volts with nasty multihundred volt spikes and line connected - discharge power supply filter caps first after unplugging). If it is scorching hot after a few minutes, then you need to check the other possibilities.

It is also possible that a defective flyback - perhaps one shorted turn - would not cause an immediate failure and only affect the picture slightly. This would be unusual, however. See the document: Testing of Flyback (LOPT) Transformers.

Note that running the set with a series light bulb may allow the HOT to survive long enough for you to gather some of the information needed to identify the bad component.

HOTs Blowing at Random Intervals

The HOT may last a few months or years but then blow again.

However, a combination of mode switching, loss of sync during bootup, running on the edge of acceptable scan rates, and frequent power cycles, could test a monitor in ways never dreamed of by the designers. A TV may suffer from similar failures due to repeated power cycling, video input selection, or channel changing. It may take only one scan line that is too long to blow the HOT. Newer horizontal processor chips are quite smart about preventing HOT killing signals from reaching the horizontal driver but they may not be perfect.

On the other hand, the cause may be along the lines of those listed in the section: HOTs Keep Blowing (or Running Excessively Hot) and just not as obvious - blowing in a few days or weeks instead of a few seconds but in this case, the HOT will likely be running very hot even after only a few minutes.

Another possible cause for random failures of the HOT are bad solder connections in the vicinity of the flyback and HOT (very common due to the large hot high power components) as well as the horizontal driver and even possibly the sync and horizontal oscillator circuits, power supply, or elsewhere.

Preventing Random HOT Failures

A bigger HOT is not the answer. A selection of the same HOT for 1700 V breakdown voltage may help but is not an option outside the design lab. Sometimes very exotic HOT type numbers occur, which are really a selection from a standard type, used for statistical failure analysis.

A separate EHT supply (only in the most expensive monitors) would also help to save the deflection transistor, but might kill its EHT twin. Of course, not an option in the field.

Soft-start circuits make a biiig difference, but are an inherent part of the design, not an afterthought.

The chance of failure is a function of almost unspecified transistor parameters, so the mere swapping of a HOT may solve it permanently.

If it is an EMI problem (like a cellular phone lying on top or the set) then obviously the cause must be eliminated. A layout change is a better remedy but out of reach of a repair shop.

More on HOT Failure

“I’m sure this has been discussed before, but I have worked on several monitors lately with shorted HOT’s, replacing that one part has fixed all of them, and I have not had a reoccurrence yet. Does something cause HOT’s to blow, or do they just short occasionally for no reason?”

Actually, we know fairly well why HOTs blow, at least in television. They almost always fail from secondary breakdown, not from average dissipation. Secondary breakdown occurs instantly if the combination of voltage and current is too high, even for only 1 line period.

Usually this happens due to a hard-start condition of a flyback converter. In case of a CRT display this usually applies to the high voltage output which is loaded by the built-in capacitance of the tube. When the FBT starts to charge that capacitance it sees a short-circuit. This causes the core of the FBT to go into saturation and the primary current rises to a multiple of what it should be.

When the HOT switches off such a large current it breaks down. That is, some HOTs break down. Most are better than spec and survive. If it survives the first hard start it will likely survive many.

Such situation occurs most likely after a picture tube flashover, when the EHT capacitance has been shorted. After about 3 line periods the current through the HOT becomes too high. Only a soft-start method can really prevent it but it is a bit hard to design a circuit.

Other causes for HOT failure may be false drive pulses, e.g. due to a bad sync input (not likely for a monitor with a slow line PLL) or due to EMI. It should not happen, but it will. Some manufacturers have better designers than others. Ahem...

Saga on Swapping of HOTs

(From: Malik (M.Dad@mmu.ac.uk)).

The prologue:

I have in for repair a Tatung monitor model CM14UAE. Originally it was dead this fault was quickly remedied by replacing the line output transistor which was ‘dead short’, causing the power supply to shut down.

Now the transistor I replaced seems to get a hell of a lot hotter than it should, when it gets to a certain temperature after about half an hour the width begins to collapse at which point I quickly switched off. If I switched off for a few seconds and back on again I would get the width back but again it quickly began to collapse.

Things you need to know:

The LOP stage is independent from the EHT transformer. i.e. there is a separate transformer for the EHT (and A1 supplies etc) with its own transistor and a separate line output only transformer with its own transistor. I have also tried substituting the efficiency diode, still no joy. I have also replaced the EW transistor and its driver. To me it seems that the transistor is not being switched properly, although the waveforms do look OK.

Original line output device 2SC3893A, which I replaced with a BU508DF (European equivalent according to the books. I also tried a 2SC3883 which used for the same job in other SVGA monitors. Both give the same problem,

I will be trying to get the original transistor in case this is the problem but I don't think it will make a difference.

And the conclusion:

Anyway after all that headache I finally received through the post the original 2SC3893A. I fitted this and left the monitor on test. Sigh of relief, the problem has gone away.

It seems the timing on this device differs from all the others I tried. The transistor runs at a reasonable temperature even after a few hours use.

The moral of this story is, use original line output transistors. Unless you are 100% sure the replacement works in its place. Don't rely too much on equivalent books, these should be used as a guide. The book I looked at specified the BU508DF as a direct replacement for a 2SC3893A, but as I know now it doesn't work properly.

The HOT should not run too hot to touch. If the replacement sizzles, it won't last long and is probably deficient in some specification. If the monitor or TV appears to work normally otherwise, try an exact replacement HOT if available before swapping other expensive parts like the flyback (LOPT). For testing, however, a substitute can usually be used - with a series light bulb and Variac.

Brief Comments on Testing the HOT

For a TV with no blown fuses that will not start, here are two quickly checks to see if the HOT is good and has power and drive:

HOT tests - check across each pair of pins for shorts (preferably removed from the circuit board). No junction should measure less than 50 ohms or so. Lower readings almost certainly indicate a bad HOT. If in-circuit, however, the reading between base and emitter will be near zero due to the secondary of the driver transformer. See the document: Basic Testing of Semiconductors. Don't be confused by internal damper diodes and B-E resistors.

Power - measure across the collector to emitter with a multimeter (with the HOT removed or if there is no deflection, this is safe with it in place). There should be solid B+ - typically about 100 to 160 V (115 VAC sets - possibly higher for 220 VAC sets). If this is missing, either there is a problem with the power supply or the emitter fusable resistor has blown (probably in addition to the HOT) and there is no return.

Drive: put an oscilloscope on the base - there should be pulses around .7 V for most of the scan (~50 microseconds) and probably going negative a couple volts at least for retrace (~12 microseconds). If drive is weak or missing, determine how startup is implemented as there may be a problem in the startup power supply or deflection IC.

WARNING: Use an isolation transformer for the oscilloscope tests (and whenever you are probing a TV in general)!!! This part of thecircuit, in particular, is usually line connected. See the document: Safety Guidelines for High Voltage and/or Line Powered Equipment.

Testing of Replacement HOTs

The following is useful both to confirm that a substitute replacement HOT is suitable and that no other circuit problems are still present. However, single scan line anomalies (particularly when changing channels and/or where reception is poor with a TV or when switching scan rates and/or when no or incorrect sync is present with a monitor) resulting in excessive voltage across the HOT and instant failure are still possible and will not result in an HOT running excessively hot.

(From: Raymond Carlsen (rrcc@u.washington.edu)).

After installing a replacement HOT in a TV set or monitor, I like to check the temperature for awhile to make sure the substitute is a good match and that there are no other problems such as a weak H drive signal. The input current is just not a good enough indicator. I have been using a WCF (well calibrated finger) for years. For me, the rule of thumb, quite literally, is: if you can not hold your finger on it, it's running too hot, and will probably fail prematurely. Touching the case of the transistor or heat sink is tricky....

Metal case transistors will be connected to the collector and have a healthy pulse (>1,200 V peak!) and even with plastic case tab transistors, the tab will be at this potential. It is best to do this only after the power is off and the B+ has discharged. In addition, the HOT may be hot enough to burn you.

A better method is the use of an indoor/outdoor thermometer. I bought one recently from Radio Shack for about $15 (63-1009). It has a plastic 'probe' on the end of a 10' cable as the outdoor sensor. With a large alligator clip, I just clamp the sensor to the heat sink near the transistor and set up the digital display near the TV set to monitor the temperature. The last TV I used it on was a 27" Sanyo that had a shorted H. output and an open B+ resistor. Replacement parts brought the set back to life and the flyback pulse looked OK, but the transistor was getting hot within 5 minutes... up to 130 degrees before I shut it down and started looking for the cause. I found a 1 uF 160

volt cap in the driver circuit that was open. After replacing the cap, I fired up the set again and monitored the heat sink as before. This time, the temperature slowly rose to about 115 degrees and stayed there. I ran the set all day and noticed little variation in the measurement. Test equipment doesn't have to cost a fortune.

Oscillation or Ringing at HOT Base?

"Could this be happening because I'm using the wrong HOT?"

At these relatively low frequencies your scope probe is probably not suspect, although you should keep loops small and not underestimate the effect of high dV/dt inside the line transformer.

First, how do we know if the oscillations were already there with the original HOT ? I suppose you have never measured that ...

Second, it is NEVER a good idea to replace a HOT with just any other type because there can be significant differences which are not at all visible in the spec. Even for specialists it's quite difficult to optimize the drive conditions for a new HOT type. You're on your own here.

Third, some oscillations are normal because the inductance of the base drive transformer does form part of a damped resonant circuit. Usually these oscillations show after switching OFF the HOT and they can be a problem if the negative Vbe is insufficient during the flyback pulse and the transistor might be turned back on, which would kill it. As a rule of thumb, Vbe should be -2 V during flyback, but there are exceptions. Depending on the HOT type, some damping resistor may have to be applied. I've never heard of oscillations during HOT ON.

If the collector waveforms (V and I) seem OK and the HOT does not overheat then maybe you shouldn't worry too much. But do check at high beam current too (max. brightness on a white picture) because then the HOT must be switched on earlier to provide the magnetizing current to the line transformer too.

(From: Alan McKinnon (a.mckinnon@pixie.co.za)).

I've run into this kind of thing several times recently on different sets, this is what I've found:

1. **Do you have a damper resistor (about 30 or so ohms) across B-E of the HOT. It can go open circuit, causing weird stuff.**
2. **Check the supply feed resistor into the transformer of the line drive circuit. These can go high, especially if it's a high value resistor dropping a supply of 120 odd volts down to 30 or so.**
3. **Check all small resistors and caps in the line drive circuit, take then out and measure them, in circuit reading are funny in this area.**

5. **Try a new drive transformer.**

Additional Deflection System Information

Why are Nearly All Horizontal Driver Circuits Transformer Coupled?

Almost every TV and monitor in the universe uses a small high frequency transformer to couple the drive signal from the horizontal oscillator to the horizontal output transistor base. There are several reasons why this is so popular:

One (probably secondary) reason is that this provides one of the isolation barriers between a line-connected HOT and flyback primary and the signal circuits of the TV.

A more important rational is that a transformer is nice easy way of impedance matching the horizontal driver circuit (100s to 1000s of ohms) to the few ohm input impedance of the horizontal output transistor base which requires upwards of several amps for proper drive. A typical driver transformer may be in the 5-10:1 turns ratio representing 25-100:1 impedance ratio.

> **A byproduct of all this is that it is unlikely for a faulty driver stage to kill the HOT. Unlikely but not impossible.**

However, there are apparently some smaller TVs that use a direct coupled drive scheme but these are definitely the exception.

S-Correction Circuits on Multi-Scan Monitors

(Quoted text from a curious but frustrated tinkerer/technician.)

“Hi there. Recently, I’ve encountered this circuit (or ones similar to it) several times in VGA monitors and I’d like to know what it’s purpose is.

```
          +-------------------+-----------------+
          |D                  |                 |
         _+--+                |                 |
      G||  __|__             _|_              __|__
S0 ----||  _/_\_ IRF620      ___ .64 uF       _\_/_
       ||_   |                |                 |
          +--+                |                 |
          |S        .64 uF    |B                |
Ground o--+-----------||------+---o * See Text  +------o To +76 V
          |S                A |C                |
         _+--+                |                 |
      G||  __|__             _|_              __|__
S1 ----||  _\_/_ IRF620      ___ .64 uF       _/_\_
       ||_   |                |                 |
          +--+                |                 |
          |D                  |                 |
          +-------------------+-----------------+
```

The IRF620's are N channel Enhancement Mode MOSFETs.

The connection at this point is to the HOT collector via the horizontal deflection yoke (HDY), width, and linearity coils."

You will probably find that 0, 1, or 2 of the MOSFETs will be turned on (S0, S1 set to ground or +15 V (typical) depending on the scan rate. This would introduce varying amounts of S-correction (E/W) depending on the horizontal scan rate.

The diodes are probably for clamping and protection. The MOSFETs are used as switches. You, in effect, get 1, 2, or 3 x .64 uF between the yoke return (the point marked '*') and ground.

This circuit is from an auto-scan computer monitor where it switches the effective S-correction capacitor to one of 3 possible values depending on scan rate.

Note that this approach is used both in multi-scan and auto-scan monitors. The multi-scan (largely obsolete technology though still used in some specific applications) has two or more discrete line frequencies and the auto-scan has a whole range of available frequencies. You would not guess this from the discrete switching of the S-correction capacitors. Obviously, the S-correction is optimized only for 3 frequencies and approximated for all others. This is generally good enough (even) for auto-scan.

The internal diodes anti-parallel to the MOSFET (A to S, K to D) are important to set the DC voltage over the extra S-capacitors to a reasonable value before they are first switched in. At lower line frequencies the extra capacitors are permanently switched on.

For each given scan frequency there is only one correct value for the S-correction capacitor. If you limit your circuit to only 3 discrete values (like 0.64, 1.28 and 1.92 uF) then the horizontal geometry can be optimized for only 3 scan frequencies.

Somewhere between these 3 frequencies there will be 2 switch-over points where more S-correction capacitance is added by the switches. Generally, around these border frequencies the geometry will

be worst (because whatever the position of the switch, there will be an error one way or the other) and it would be wise to switch over near some little-used frequencies and thus optimize for the much-used frequencies like 31, 38, 48 and 64 kHz. For the other scan frequencies, the geometry will then be only approximately correct. Luckily, S-correction is not very critical.

For any given scan frequency, the position of the MOSFET switches is constant: either on or off. These are not used in a switched mode.

There will be one or two other MOSFET switches that switch at a line scan rate in order to take care of the correct dependency of the (average) supply voltage and E/W voltage in function of the scan frequency.

There is a difference in the horizontal deflection circuit of a TV versus an auto-scan monitor. In the diode bridge of a TV, the deflection circuit is in the upper half of the bridge and the “bridge circuit” is in the lower half of the circuit. The E/W amplifier sinks current from the centre node (and dissipates). The VB supply voltage is constant.

In the diode bridge of a auto-scan monitor, the deflection circuit is in the lower half of the bridge. This makes the S-correction capacitor grounded and thus easier variable (without need for level shifters, opto-couplers, etc). The E/W amplifier sources current into the centre node. The VB supply voltage is made variable, linearly proportional to the line frequency, by means of a switched-mode down-converter topology. The same topology is also used for the E/W amplifier, which now actually delivers power to the circuit. With this topology you can

have a constant (even regulated) EHT and a constant deflection current amplitude, independent of the line frequency.

“In another similar monitor, this circuit had completely self-destructed and taken out a few other things too (fire). The monitor shuts down immediately unless the HOT is disabled or connections A, B, and C are all broken (no other combination works). It almost seems like it’s used to accommodate or change the horizontal frequency for different video modes. For some reason, the monitor is now powering up so seems like it might be an intermittent short somewhere.”

By disconnecting A,B,C you effectively take the coils of the horizontal deflection yoke (HDY) out of the circuit. By disabling the line transistor (HOT) there remains only DC voltage over the bridge- and S-correction capacitors. Either way there is no voltage over the HDY. I would suspect a short or arcing in the deflection coil. Just a wild guess, though.

There is enough energy present in the deflection circuit (also in the HDY) to create a very nice fire, let there be no doubt about that. A loose contact in series with this circuit is potentially fatal.

More on Horizontal Driver Circuits

Usually, the primary voltage is constant when the driver transistor is ON and thus the HOT is OFF. Then when the driver switches OFF, the stored magnetic energy switches the HOT to ON.

This is called non-simultaneous base drive, which is most common. The primary voltage that you see then is mostly a transformed version of the secondary voltage, over the series base impedance. The voltage at HOT=ON is not forced from the primary side.

Usually the "cold" side of the primary of the driver transformer is connected via a power resistor and filtering electrolytic capacitor to the B+. The R determines the average voltage and thus the base drive current. Higher R means less base drive and vice-versa. Varying the value of this resistor is the first choice for minimizing the power dissipated in the HOT.

The filtered DC voltage at the cold side is (typically) a little over ½ * V(B+). Then when the driver switches off the voltage at the hot side (of the primary) will be higher, but typically not higher than V(B+). But how high exactly is a coincidence.

Why do Some Monitors Fail if Driven at the Wrong Horizontal Frequency?

I think it should not have failed. It is the purpose of the deflection processor to guard that the line deflection never runs at a forbidden frequency. It is possible that such protection is not good enough, that when the PLL is not in lock it might generate a very irregular line drive. That can prove to be immediately fatal to a line transistor. All it takes is one line length that is too long, followed by a flyback pulse that is too high, and it's all over. Second breakdown, terminal.

Trying a too high line frequency is usually not harmful, generally your EHT will be too low and your deflection current amplitude too. The HOT might eventually die from overheating due to bad drive conditions, but otherwise any decent monitor should be able to withstand it. In the better cases it simply refuses to sync on an illegal frequency.

1. **While increasing the frequency of the horizontal drive all other factors being equal should not result in HOT death, all other factors are not always equal. The sync circuits may select an improper set of voltages, the drive waveform (as mentioned) may be insufficient, etc.**
2. **The sync may lock to a submultiple so the drive may be at ½ H resulting in a too long on-time and poof.**

As noted, this can be a one shot affair - absolutely no warning. My recommendation remains to attempt if at all possible to obtain the specs for any monitor you intend to use.

Tweaking the Deflection Rates in a Fixed Frequency Monitor

Pulling a fixed frequency monitor by more than a few percent will likely be a problem. I know this is not the answer you were looking for but getting a new inexpensive video card may be a better solution.

If not, you are looking for an adjustment called horizontal oscillator, horizontal frequency, or horizontal hold. If you do tweak, mark everything beforehand just in case you need to get back to the

original settings. There is some risk - changing it too far may result in damage either immediate or down the road - I have no idea.

Here is a discussion about modifying a monitor to run at other scan rates than for which it was originally designed (in this case, a lower one):

> **"I would like to convert IBM XGA2 (39.4 KHz JH) monitors (9515, 9518) to work at VGA (31.4 KHz H) rates.**

I have the schematics, and with datasheets/application notes from chipmakers' websites altering the scan-frequencies and the mode-switching logic has been relatively straightforward.

That's as regards the 'small-signal' bits (and frame output), to leave a 39.4 KHz scan for 75 fps graphics and provide 31.5 KHz for the 400-line DOS text (VGA startup) mode, and 350-line graphics.

But the HOTs blow up at 31.5 kHz: after a while in the first of a number of 9515s, almost instantly in 9518. The corpses and heatsinks are very hot, as in 'high temperature' as well as function :-((“

Blowing up the HOT after minutes is due to bad base drive, or (much more rare) due to LOT core saturation. Blowing up a HOT immediately is due to too high collector pulse.

"The base drive looks fine on a 'scope as regards holding the HOTs (or now an experimentally-substituted forward diode) firmly saturated for the longer 'on' time, and then sharply/cleanly turning them off."

There's more to a good base drive than just 'looking fine' on a scope. The aim is to minimize the dissipation in the HOT. This requires just the right amount of base current and reducing it in a particular manner at the end of each line. (A process that we call 'de-holing', removing all the holes from the high-impedance collector region, this must not go too fast.)

Too little base drive current will cause the collector voltage to start rising too early, before the beam has reached the right end of the screen. The HOT goes out of saturation too early, causing dissipation.

Too much base drive current will cause the collector current to reduce too slowly during the beginning of flyback. The HOT goes out of saturation too late, also causing dissipation.

Usually for lower line frequency you need a bit more base drive.

"I have only a rather vague mental picture of how a LOPT works. I think that, as a load on the HOT, it is almost purely inductive from turn-on (though not from the EHT-generating turn-off)."

If there are secondary scan-voltage rectifiers then they add to the load during (beam) scan. Otherwise it is always inductive. During flyback, the flyback capacitor and the secondary flyback rectifiers cause the characteristic flyback pulse shape.

> **"Hence I suppose that the longer 'on' period allows the current to increase to a higher (and destructive) level."**

Not the higher current in itself is destructive, but the increased magnetic energy is. During flyback, ½*L*I^2 is converted to ½*C*V^2 in the flyback capacitor. More energy means more voltage over the HOT. Over 1500 V peak it will be destroyed immediately.

> **"If magnetic saturation were to be reached, it would even look more like a dead short than an inductance."**

That's true, but it occurs mainly due to excess beam current. Secondary flyback load causes the primary scan current to rise.

> **"My questions are twofold: (1) how correct is my understanding?"**

Fair enough. You can get a fair idea by running simulations with ideal circuit models. But to understand what happens inside a HOT you need very advanced models. Which don't even exist (yet)!

> **"(2) More to the point, what solution is there?"**

You're doing a good job guessing. I'll let you continue.

"One that springs to mind is to reduce the voltage of the HOT's supply, something like proportionally to the increase in 'on' time, so that the peak current is back to what it is at the higher frequency."

Exactly. Peak current and more importantly peak voltage, because then also the EHT will be kept constant.

"This would be a non-trivial task, both to provide a second voltage (at quite high current) and to switch between them."

Maybe not trivial but a lot easier than you think.

"Though some multi-frequency monitors have such multiple (switched) supplies, I don't think all do: what alternatives can be adopted? How does one calculate in this area, or is it (unfortunately) a matter of having LOPTs intended for the purpose?"

The LOPT must be optimized for the higher line frequency and the corresponding short flyback duration. For lower line frequencies, you want to reduce the B+ voltage so that it is proportional to the line time. This is in fact very easy if you use a switched-mode down-converter (is that called a 'buck'?) and you make the on-time of the switch constant. Now the line frequency may be varied over a wide and continuous range. This gives near constant EHT too.

On other monitors, a voltage determined by the detected scan rate is returned to the power supply in place of the usual zener reference to adjust its output.

You can use an extra filter coil to provide constant B+ to the line deflection circuit or you can use the LOPT primary for that. There are some subtle problems with which I will not bother you.

It may be necessary to reduce base drive current for line frequencies beyond a certain value.

The 'only' other thing left to do is to keep geometry correct for the various display modes. Mainly by switching in more or less S-correction capacitance (using FETs or even relays).

Don't assume that you will be able to re-invent the multi-scan monitor on your own. I think you will find that you have insufficient resources to do that.

Honestly.

Yoke and Interlocks

"I was asked a question today that I never thought of much before. If you remove the yoke (unplug it) from a TV or monitor is the high voltage still present and if so can this cause damage to the set. Thanks"

The answer is an unqualified maybe on all counts.

Some have an interlock so you lose power to the deflection/set if the yoke is unplugged - found that out on a Magnavox chassis that would not do anything without the yoke connections.

Those that continue to have power may result in damage - at the very least, if the HV is present, you will be drilling a hole in the center of the screen since deflection will be absent. The horizontal deflection will be detuned possibly resulting in overheating, excess HV, etc.

If you do try this, I recommend using a Variac and carefully monitoring the CRT for presense of a very bright spot (which will turn into a very dark spot quite quickly) as well as an excessively hot HOT.

BTW, disconnecting the yoke may be desirable to troubleshoot a horizontal deflection/high voltage if the yoke is suspect. If the yoke is loading the deflection output due to shorted turns, disconnecting it may allow high voltage to come up - just go slow and nothing will blow.

(From: Stefan Huebner (Stefan_Huebner@rookie.fido.de)).

Some yoke plugs have a jumper wire to remove +B from the flyback when pulling it. But this may still damage the SMPS since they are not all build for running without a minimum load. Some yoke plugs only have the four yoke wires connected; in those sets HV will build up when the plug is pulled and you may even destroy something in the flyback area (most likely the HOT) because the horizontal deflection yoke is an essential part of the flyback circuitry (exception: some monitors, foe example Eizo, which have separate HOTs for the flyback and the horizontal yoke).

Why the Yoke is Needed to Keep the Horizontal Deflection System Happy

If you unplug the yoke (even if there is no interlock), while the system may still work to some extent, performance will be poor. High voltage will be reduced and parts may overheat (and possibly blow up).

One reason to do this at all is as a quick test to determine if the yoke is defective. While the resulting waveforms will not be totally correct, they should be much better than with a shorted yoke installed and there may be enough HV to get a spot on the screen. Caution: It may be quite bright. See the documents: Notes on the Troubleshooting and Repair of Computer and Video Monitors or Notes on the Troubleshooting and Repair of Television Sets for more info and precautions.

Another more fun reason is if it is desired to use the flyback subsystem of a defunct TV, monitor, or computer terminal as a stand-alone high voltage power supply - but details are left as an exercise for the highly motivated (and cautious!) student. See the document: Salvaging Interesting Gadgets, Components, and Subsystems for more exciting details.

WARNING: High voltages and possibly line voltage present at HOT, yoke, flyback outputs, and elsewhere!

(From: Jeroen Stessen (Jeroen.Stessen@ehv.ce.philips.com)).

Of course, just removing the yoke doesn’t work. The flyback capacitor is tuned for the presence of both inductances: line transformer and deflection coil. If you remove the deflection coil then the remaining primary transformer inductance is about 5 times as large. So, rule-of-thumb, you would have to decrease the flyback capacitor by a factor of approximate 5. But that’s not all:

Without the deflection coil, a lot less current runs through the horizontal output transistor. So, in all likelihood, it will now be overdriven. So you need to reduce the basedrive. But that’s not all:

If you remove the picture tube capacitance and the deflection coil then all peak energy demand must be delivered from the primary winding of the line transformer. Even the shortest peak load will cause saturation. The parallel deflection coil will at least lend some temporary energy, and the picture tube capacitance does an even better job. A good high-voltage source without the benefit of a deflection coil is more expensive...

If you must get rid of the ‘ugly’ deflection coil, then you may want to replace it with an equivalent ‘pretty’ coil. But:

It must be able to carry the peak current without saturation (a deflection coil has such a huge air gap that it can not possibly ever saturate, but a smaller coil can).

It must have a low enough dissipation so you might have to wind it with litz-like wire (multi-stranded isolated), do not underestimate the losses in high-frequency coils, mostly due to skin- and proximity-effect.

Yes, it can be done, good luck.

And you might want to add a discrete high-voltage capacitor. How to isolate the wiring (corona discharge!) is left as an exercise to the reader... (We pot them in convenient blocks).

Probing TV and Monitor Yoke Signals

Due to the particular nature of the signals on the deflection yoke, special techniques must be used to safely view them on a scope. Note that the following also applies to some extent to deflection signals in tube-type video cameras and other similar devices as well.

You cannot put a ground clip on either pole of the line yoke, because one side carries the flyback pulses which are approx. 1000 Vpp and the other side carries the S-correction voltage which may be 100 V average with a (?) 50 Vpp line parabola. Both signals are at line frequency (15.75 kHz and up). You need a 100:1 oscilloscope probe for the 1000 Vpp signal! The field coil carries lower voltages (order of 50 Vpp max) and at field frequency (50 to 120 Hz).

Usually you connect the scope ground to a large heatsink, unless that carries a warning label that it is not grounded... ALWAYS check first to identify a proper ground and use an isolation transformer for safety since even this may not be the same as the power line ground.

If you have a current probe for your scope, this can be used to monitor the various current waveforms. I have used my Tektronix current probe to view the yoke current on TVs. The rendition of the horizontal deflection current waveform is quite good. However, the vertical suffers from severe distortion due to the low frequency cutoff of this probe.

You can build a not-very-fantastic (but quite usable) current problem using a split ferrite core of the type used on keyboard and monitor cables (preferably one that snaps together). The following will work:

Wrap seven turns of insulated wire around one half of the core.

Solder a 2.2 ohm resistor across the two leads to act as a load.

Connect to the vertical input of your scope via a coaxial cable or probe.

You can experiment with the number of turns and load resistor value for best results.

To use your fabulous device, insert one and only one of the current carrying wires inside the ferrite core and clamp the two halves together.

For a typical TV horizontal deflection yoke, this results in about a .3 V p-p signal. The shape was similar to that from my (originally) expensive Tektronix current probe. Enjoy the show! Due to its uncompensated design, this simple probe will not work well (if at all) for low frequency signals.

Breathing Compensation

Breathing is a change in picture size caused by a variation of the EHT voltage due to varying beam current loading. The EHT has a typical output impedance of (approx.) 1 M Ohm. Average beam

current varies between 0 and 2 mA, so the voltage drops by 2 kV (from 30 kV), or worse. At lower EHT, the electron beam is easier to deflect, so the picture size will increase.

Brighter picture -> higher beam current -> lower EHT -> larger picture. That's the law of physics.

The breathing can be compensated by decreasing the deflection current amplitude as a function of the beam current. A voltage called "EHT-info" is generated from the beam current as delivered by the line transformer. This is fed to the deflection circuit for feed-forward correction. For horizontal deflection this means feeding it to the East-West modulator.

And here's the catch for you Americans: many USA sets don't have an East-West modulator! Most picture tubes (for the USA) with 90 or 100 degrees deflection don't need (much) pin-cushion correction, so there is no fundamental need for the East-West modulator and so there is also no correction possibility for the anti-breathing. There are other options for corrections, like creating a deliberate higher output impedance for the V+ deflection supply etc., but these are passive measures which will lack accuracy.

Sets with 110 degrees deflection angle (common in Europe) will need active East-West correction and should also perform adequate anti-breathing. Although that is still difficult enough, I should know...

The LD/DVD "Video Essentials" contains test pictures to check your breathing performance. It advises you a simple counter- measure: reduce the beam current by lowering the contrast setting ! This will also improve the sharpness (less spot blooming) and increase the lifetime of the picture tube (less burn-in of the phosphors). But you need to darken the room because the picture will obviously be much darker... (http://www.videoessentials.com/)

VIDEO GAME MONITOR REPAIR

Copyright October 1st, 1990 By Randy Fromm

Troubleshooting Horizontal Deflection Failures

Most video game monitor failures are pretty straightforward. A quick glance at the screen will usually point you to the general area of the problem. A missing color will lead you to the video amplifier circuits while a horizontal line will point to a loss of vertical deflection.

But a failure in the horizontal deflection circuit can be a bit more difficult to figure out because the monitor will appear to be completely dead. The characteristic high pitched squeal of a functioning monitor will be missing and there will be no picture or brightness of any kind on the screen. That's because the horizontal deflection circuit is used to drive the high voltage unit (see RePlay, June 1990 for more on high voltage units.) Without high voltage, there is no picture at all.

The Horizontal Deflection Circuit

The horizontal deflection circuit is similar in most monitors; in fact, it is almost identical in just about every video game monitor in use today. Inside an IC on the monitor's printed circuit board, a circuit known as the "horizontal oscillator" is used to generate an alternating current signal of approximately 15,750 Hertz. Although this signal will eventually be used to power the horizontal deflection coil in the yoke (as well as the high voltage unit) it is still very weak at this point (only about 1.5 VAC); it has to be amplified.

The output of the horizontal oscillator is connected to the input of the horizontal drive transistor where it is amplified to obtain an output of around 100 VAC. A small transformer (appropriately called the horizontal drive transformer) is used to change this output into a high current AC signal. This is used to drive the horizontal output transistor.

The horizontal output transistor is the hardest working transistor in monitor. All the current for the horizontal deflection coil in the yoke and the flyback transformer in the high voltage unit passes through the horizontal output transistor. In fact, approximately 80% of the power consumed by a video game monitor is controlled by the horizontal output transistor.

Troubleshooting Horizontal Failures

If the monitor has a blown fuse, chances are excellent that the horizontal output transistor has shorted. You can check it with your digital multimeter. Set the meter to the diode test setting. If your meter does not have a diode test, use a low resistance scale. Remove the power to the monitor. Ground the black meter lead to the chassis and touch the red meter lead to the collector of the horizontal output transistor. If the meter displays a low resistance or short circuit, you've found the culprit. A bad high voltage unit also may cause the fuse to blow. In fact, the horizontal output transistor and high voltage unit will often fail together (the bad high voltage unit having caused the transistor to fail.)

Horizontal deflection problems that do not blow the fuse are somewhat more difficult to troubleshoot. There are a few things that can cause the horizontal deflection to become inoperative. One may have nothing to do with a horizontal failure at all!

Most monitors include a circuit known as an "X-ray protector" or "high voltage shut-down." The purpose of this circuit is to shut down the high voltage if it becomes excessively high in voltage. It does this by killing the horizontal oscillator circuit. This prevents the monitor from emitting excessive X-rays.

To figure out if the horizontal deflection circuit is really defective or if it has been shut down by the X-ray protector, you should start your troubleshooting by disabling the shut-down circuit. This will be different in each type of monitor, so here are some commonly used video game monitors and the method of disabling the X-ray protector:

Electrohome	**- Remove transistor X701.**
Hantarex MTC 900	**- Unsolder and lift one end of resistor R152.**

Hantarex MTC 9000	**- Unsolder and lift one end of diode D10.**
Orion	**- Unsolder and lift one end of diode D401.**
Sharp Image	**- Unsolder and lift one end of diode D410.**
Wells-Gardner K4600 series	**- Remove transistor TR353.**
Wells-Gardner K7000 series	**- Unsolder and lift one end of diode D12.**

Note: Quite a few of the monitors use an HA-11235 integrated circuit for the horizontal oscillator. Pin 9 of this IC is used for the shut-down input. If you see a zener diode connected to this pin, lifting either end of the diode off the board will disable the shut-down circuit.

With the shut-down circuit disabled, apply power to the monitor. If the monitor now gives you a picture, the horizontal circuit is working. Your problem lies elsewhere (probably in the voltage regulator circuit.)

If the monitor is still dead, you need to make a few more tests. Measure the voltage at the collector of the horizontal output transistor. It should be around +110 to +130 VDC. WARNING: NEVER TEST THE VOLTAGE AT THE COLLECTOR OF THE HORIZONTAL OUTPUT TRANSISTOR IF THE HORIZONTAL DEFLECTION CIRCUIT IS WORKING PROPERLY! This test should only be performed if the monitor is dead. If you hear the high pitched squeal, or if a neon lamp glows when held near the flyback transformer (see RePlay, June 1990) measuring the collector voltage can damage your meter.

If the collector voltage is missing, there are only a few things that can be wrong. The most likely is a crack in the printed circuit board. Also, examine the solder joints around the high voltage unit. You may find some cracks or fractured solder joints. There is a highly remote possibility that the high voltage unit may be bad.

The Wells-Gardner K4900 series has a common problem with the jumpers that carry the +130 VDC power supply around the perimiter of the board. One of the jumpers is located in the position on the board that is sujected to stress from the plastic clip that holds the board in place on the chassis. Removal and replacement of the board can cause this jumper to break, cutting off the voltage to the horizontal output circuit.

If the collector voltage of the horizontal output transistor is good, test the voltage at the collector of the horizontal drive transistor. If this voltage is missing, the primary winding of the horizontal drive transformer or the resistor that is in series with it may be open. The resistor will generally be 5 watts at 2.2K to 3.8K ohms. Check these with the power turned off. Naturally, you want to check for bad solder joints here as well.

If the collector voltage measures at around 50 VDC, switch your meter to read AC volts and measure it again. If you read approximately 50 VAC, the horizontal drive circuit is probably working properly. Your problem is most likely an open secondary winding in the horizontal drive transformer or broken traces and/or bad solder joints between the output of the horizontal drive transformer and the base of the horizontal output transistor. There is a remote possibility that the horizontal output transistor is bad but this is highly unlikley. As the horizontal output transistor is often a specialized one (with an internal resistor and diode) the best test here is substitution with a known good component.

If the collector voltage of the horizontal drive transistor measures at +110 to +130 VDC, turn off the monitor and test the horizontal drive transistor. You must unsolder and remove the transistor from the printed circuit board to test it properly. Horizontal drive transistor failure is not too common, so don't be too hopeful.

If the drive transistor tests good, re-install it, apply power to the monitor and measure the voltage at the base of the horizontal drive transistor. It should measure at around .4 VDC and 1 VAC. If you have performed all the previous tests and still haven't found the problem, it probably won't. You probably will measure 0 VAC. This means that you do not have an output from the horizontal oscillator in the integrated circuit. Before you declare the IC to be defective, you should test to make sure that the IC has power (Vcc) to it. Most of the time this will be around 12 VDC. As before, this connection will vary from monitor to monitor. Here are some common monitors and the Vcc connection for each:

Electrohome	**- IC501 Pin 6.**
Hantarex MTC 900	**- IC2 Pin 2.**
Hantarex MTC 9000	**- IC2 Pin 15.**
Orion - IC401	**- Pin 11.**
Sharp Image	**- IC401 - Pin 11.**
Wells-Gardner K7000 series	**- IC2 Pin 16.**

Of course, any monitor that uses the same IC as those listed above, will use the same pin number for the Vcc input.

If the input voltage to the integrated circuit is okay, the IC itself may be defective. This is not a very common problem but at this point the IC should be replaced as you have all but eliminated everything else. If the Vcc power input to the integrated circuit is missing, trace the circuit back to see where it comes from. In general, the Vcc power for the IC comes from a 6.8K to 7.5K, 3 watt resistor that is connected to the +110 to +130 VDC power supply. If this resistor opens, it will cut off the power to the IC.