Understanding Horizontal Stages Of Multi-Frequency CRT Video Displays

Fourth In A Series Of Articles Covering Multi-Frequency Horizontal Stage Analyzing

Multi-resolution monitors not only change the overall horizontal deflection or picture width but must change the picture width dynamically from top to bottom.These changes to the horizontal deflection width produce pincushion correction, trapezoid correction and other horizontal yoke current modifications. This article briefly reviews the horizontal yoke's tuned circuit and examines horizontal centering and pincushion correction. Common methods and circuits are discussed.

This is the fourth article in a series of articles on understanding the horizontal stages of multi-frequency CRT video displays. The first article in this series covered common horizontal output stage configurations (Sencore News 178). The second article began analyzing horizontal yoke current and associated components (Sencore News 179). The third article examined how current in the horizontal yoke was modified by components in the yoke's LC tuned circuit (Sencore News 180).

Putting It All Together

In the past articles, the horizontal yoke and key components in the yoke's tuned circuit were discussed. Figure 1 shows the key horizontal deflection components including the linearity coil, yoke, and S-shaping capacitors.

Recall that the CRT's electron beam has a slightly farther travel distance to the edge of the CRT compared to the middle. The difference causes an increase in beam deflection at the edges compared to the center. The S-shaping capacitor produces a faster rate of yoke current change at lower current levels when deflection is near the center of the CRT. The rate of current change slows at higher yoke currents when deflection is near the edges, By speeding up the current change in the middle and slowing it at the edges, the travel distance error is offset to produce a linear picture.

In a multi-resolution or multi-frequency video display, the value of the S-shaping capacitor needed for one operating frequency or range of frequencies is not the same as another frequency or range. At higher operating frequencies, the S-shaping capacitor must be a lower value to tune the yoke's LC circuit to a higher frequency.

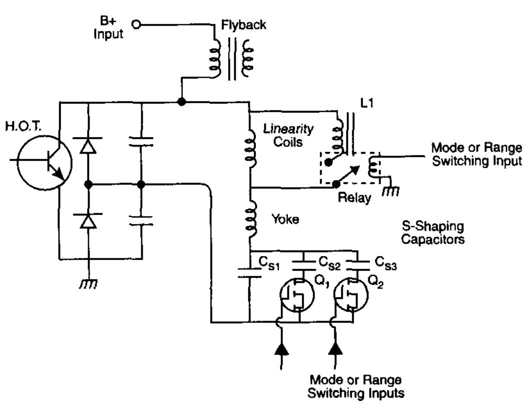


Fig. 1: A horizontal output stage showing the three horizontal yoke components and key component switching.

Figure 1 shows how switching MOSFET transistors are commonly used to switch in Sshaping capacitors to the circuit. At the highest frequency mode or range, all the transistors are switched off or open, leaving capacitor Csl as the only capacitor in the circuit. At a lower operating frequency or range, Cs2 is added to the circuit when Ql is switched on by the mode control circuits. This increases the circuit capacitance, lowering the LC resonant frequency to achieve the proper rate of yoke current change and maintain proper S-shaping for the yoke current. At the next lower operating frequency or range, Q2 is switched on. At still another yet lower operating frequency, Ql and Q2 are both switched on.

The proper S-shaping capacitor is required to properly tune the yoke's LC circuit to the horizontal output stage and its operating frequency. The operating frequency of the horizontal output stage is a result of the horizontal drive frequency which determines the switching rate of the horizontal output transistor. An improper S-shaping capacitor value causes increased or decreased deflection, non-linear deflection between the center and edges, and decreased efficiency resulting in more B+ supply and H.O.T. conduction current.

From the previous articles, you recall that a linearity coil is another key component in the horizontal yoke's tuned circuit. The linearity coil is needed to offset for the series voltage drop developed across the resistance of the yoke coil. As current changes in the yoke, a voltage drop develops across the series resistance of the coil. The voltage adds or subtracts from the voltage in the S-shaping capacitor. As a result, the rate of current change decreases as the beam scans from the left to right resulting in asymmetric picture distortion. The CRT beam travels more slowly on the right side of the screen compared to the left. This causes equal distance vertical lines of video to be squeezed together on the right side of the screen compared to the left.

A linearity coil compensates for the series voltage drop across the parasitic coil resistance by presenting the opposite or negative resistance characteristics to the tuned circuit. A linearity coil is an inductor or coil that magnetically saturates its core at low current levels (saturable inductor) and has a premagnetising core. As the yoke current changes, the voltage developed across the linearity coil has the desired voltage/current characteristics to offset the series voltage of the yoke resistance. The result is the desired yoke current shape and a uniform scan rate of the electron beam across the CRT face. The linearity coil is often adjustable to more closely offset for linearity variations of the deflection circuit.

In a multi-frequency monitor, the rate of the yoke current change increases or decreases with a change in horizontal frequency. In addition to the S-capacitor value change, a modification may be needed to the linearity coil characteristics. Linearity coils may be switched into the deflection LC circuit at different operating frequency modes or ranges. Typically the coils are switched in or out of the deflection circuit with a relay(s).

Switching relays in the deflection circuit typically have contacts which are normally closed when the coil is not energized. At higher frequency modes or ranges, the inductance of the linearity coil is decreased. In Fig. 1, the relay is normally closed at high frequencies to reduce the linearity coil value. At low frequency modes or ranges, the relay is energized to place L1 into the circuit, increasing the inductance value.

Common Centering Circuits For Horizontal Deflection Control

Horizontal centering circuits are included in most horizontal deflection and output stages. Centering circuits are needed to offset for slight imperfections in the yoke waveform which results in a slight DC voltage across the yoke and picture shift to the right or left. In some multi-frequency monitors, a user adjustment may be included in the centering circuits enabling the user to vary the horizontal position. In other multi-frequency monitors, user controls for horizontal positioning are part of the horizontal **AFC** or phase circuits. These position controls vary the phase relationship between horizontal sync and the deflection retrace pulse electrically positioning the video on the CRT

Changing the position or center of horizontal deflection as seen on the CRT requires that a continuous current be made to flow in one direction through the yoke coil. A steady DC current produces a magnetic field which deflects the CRT beam. The direction of current determines the magnetic field polarity and which way the beam is deflected. Increasing the level of DC current strengthens the magnetic field increasing the deflection shift.

A continuous current through the horizontal yoke coil can be made to flow by producing a DC voltage potential across the yoke coil. One common method to produce a voltage potential and centering current is with a centering network consisting of two diodes and a variable potentiometer balanced between them (see Fig. 2A). The wiper of the potentiometer produces a slightly negative or positive voltage difference between the B+ supply voltage input to the horizontal output stage and the other side of the yoke. By varying the horizontal centering potentiometer, DC current flows in the yoke, shifting the deflection to the right or left. This network produces only a slight voltage difference and offers a limited horizontal position or centering range.

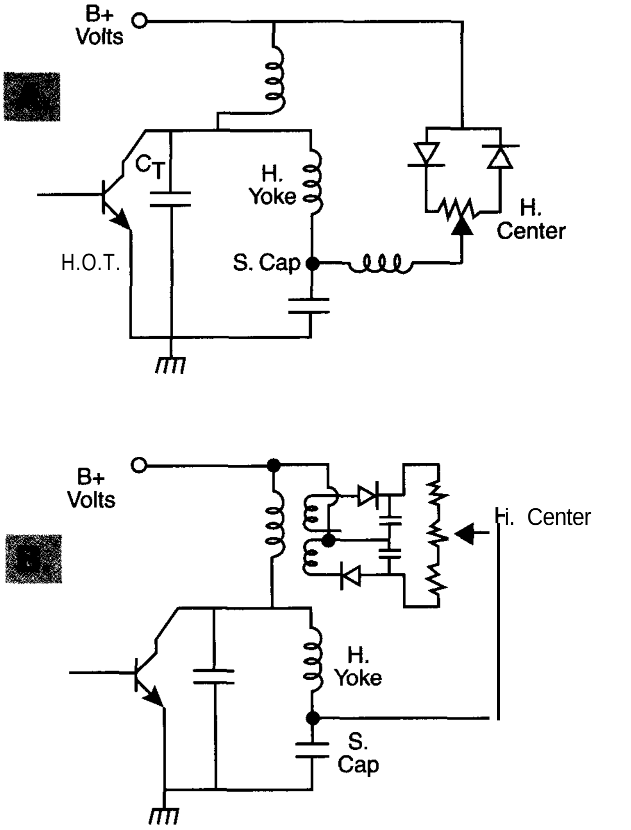


Fig. 2: *Horizontal centering* circuits *produce DC current in the yoke to shift the center of the CRT deflection.*

To increase the range provided by the horizontal centering control, some multi-frequency monitors add and subtract voltage to the B+ width transformer or flyback induced voltages (see Fig. 2B). The transformer induced voltages increase the voltage difference across the yoke in either polarity, increasing the deflection shift and range.

The B+ voltage is typically applied to a floating center point of the transformer secondary winding. Voltage induced into the secondary windings are rectified and filtered. The voltages are of opposite polarity, adding or subtracting to the B+ supply voltage applied to the center. A resistor network is connected across the output voltages with a potentiometer providing a range of DC voltage to the other side of the yoke. A substantial voltage difference of either polarity results as the width control is varied through its range. The result is an increased DC current of either polarity through the yoke and a wider horizontal centering range.

Horizontal Deflection Pincushion Control

Horizontal scan lines are repeatedly produced from top to bottom during a vertical field. Each horizontal scan line represents a complete horizontal cycle including trace and retrace periods in the horizontal output and deflection circuit. If an equal amount of alternating current is produced in the horizontal yoke each horizontal scan line, a video picture would be produced similar to that shown in Fig. 3. Equal distant lines of video from the center to the edges would be curved from the top to the bottom of the CRT. Pincushion distortion is the common name for curved picture edges.

Pincushion distortion is produced by a difference between the travel distance of the CRT's electron beam between the center and top or bottom of the CRT. The difference in travel distance results from making the CRT face as flat as possible. Recall that the travel distance from the center to the edges of the CRT are caused by the shape of the CRT and corrected with the S-shaping capacitor.

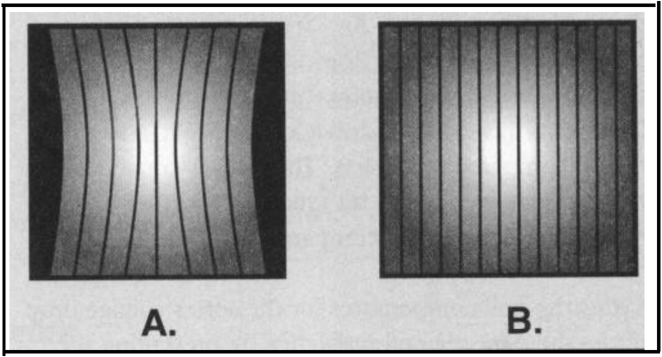


fig. 3: Pincushion distortion is produced by a difference between the travel distance of the CRT's electron beam between the center and top or bottom of the CRT.

The distortion in deflection between the middle and top or bottom of the CRT results when the CRT's electron beam travels slightly farther from the influence of the yoke's magnetic field to the top or bottom of the CRT compared to the middle. The deflection distance steadily increases from center to the top or bottom. This results in an increasing amount of deflection for each new horizontal line above or below the center of the CRT.

To correct for pincushion distortion, more yoke current is needed during the horizontal scan lines in the middle of the CRT or vertical field to increase deflection width. More specifically, the amount of horizontal yoke current would need to increment slightly higher each horizontal line as the vertical field is scanned from the top to the center of the CRT. Then the horizontal yoke current would need to decrement slightly each horizontal line from the center to the bottom of the CRT picture. By dynamically varying the yoke current by the proper amount each horizontal line during the vertical field, the picture edges are straightened.

Pincushion correction is the process of increasing the horizontal yoke current gradually over the first half of the vertical field and reducing it gradually over the second half. This dynamic change to the horizontal yoke current is also described as modulating or varying the yoke current at a vertical rate. The process is also known as east/west correction.

To better understand pincushion correction, consider the methods and circuits described in the previous article for adjusting deflection width. Pincushion correction is simply the process of steadily increasing and decreasing the deflection width during the vertical scanning process from the top to the bottom of the picture. In fact, most of the circuits and methods for horizontal width control as discussed in the previous article are also used for pincushion correction.

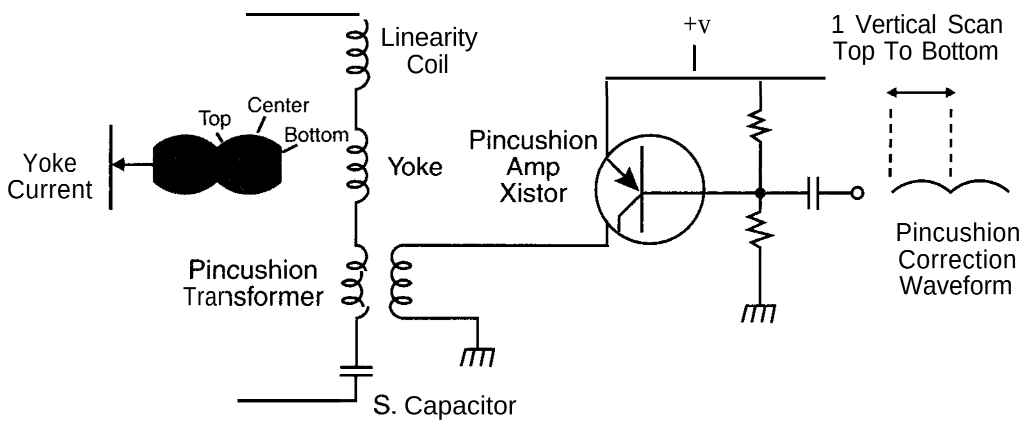
There are three common methods used to modulate the yoke current to correct pincushion or east/west distortion. They include:

1. Transformer modulation
2. Modulating voltage division in series retrace capacitors (split damper output)
3. B+ voltage modulatian

All pincushion correction methods involve applying a changing voltage to the horizontal deflection width control circuit. The changing voltage is seen as a voltage waveform on an oscilloscope. The waveform is correctly called a pincushion or east/west correction waveform as shown in Fig. 4.

The pincushion correction waveform is taken from the vertical circuits to properly phase the correction voltage with vertical sweep. The waveform is correctly shaped and amplified to provide the desired correction in horizontal deflection width. A pincushion level control is common in multi-frequency monitors. The level control increases or decreases the peak-to-peak voltage of the waveform which changes the amount of pincushion or deflection width correction. Too little amplitude cannot fully correct for the pincushion causing the picture edges to bow inward. Too much amplitude causes the picture edges to bow outward.

The pincushion correction waveform is applied to the horizontal deflection circuit. A common method of varying or modulating horizontal yoke current is with a pincushion transformer. A winding of the pincushion transformer is placed in the deflection circuit with the yoke, S-capacitor, and linearity coil. The pincushion transformer changes its inductance depending on the current and magnetic field produced by the pincushion amplifier transistor. In Fig. 4, the pincushion amplifier transistor conducts more or less current in the pincushion transformer winding as the waveform increases and decreases. The result is an increasing level of yoke



Fig, 4: A pincushion transformer with a correction voltage applied to it varies the horizontal deflection width from the top to bottom of the CRT.

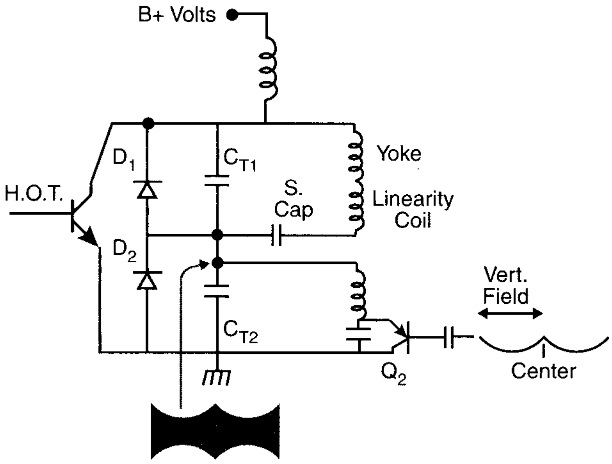


fig. 5: Pincushion correction can be made by varying the division of voltage to the Ct capacitor through each vertical field, dynamically changing the horizontal deflection width.

current from the beginning of the vertical field to the middle, and a decreasing level from center to the bottom of the vertical field.

Multi-frequency monitors with combination horizontal output stages commonly use a split damper diode stage to perform pincushion correction. The split damper horizontal output stage has two retrace capacitors in series. Width control results when the division of voltage induced into the capacitors during retrace is modified. There are two methods used to modify voltage division in the capacitors. One method uses an LC circuit with a variable conduction transistor (Fig. 5), and the second method used a PWM driven switching transistor (Fig. 6).

In Fig. 5, the pincushion waveform varies the conduction of transistor Q2, changing the division of induced voltage between Ctl and Ct2 during each vertical field. An increasing amount of voltage is induced into Ctl for the first half of the vertical field, and decreasing amount during the second half of the vertical field. The deflection width is varied accordingly to correct for pincushion distortion. While more voltage is induced into Ctl, less is induced into Ct2, producing the Ct2 voltage waveform to ground, as shown in Fig. 5.

In Fig. 6, the pincushion correction waveform is used to generate a pulse width modulated drive signal to the switching transistor Ql .A PWM drive pulse occurs each horizontal line for a total number of pulses each vertical field equal to the number of horizontal scan lines. To decrease deflection, the pulse width is narrowed. To increase deflection, the pulse width is increased. The pincushion correction waveform is input to a pulse width control circuit to vary the pulse width drive applied to **Ql .** The horizontal deflection is varied according to the pulse width correcting for pincushion distortion.

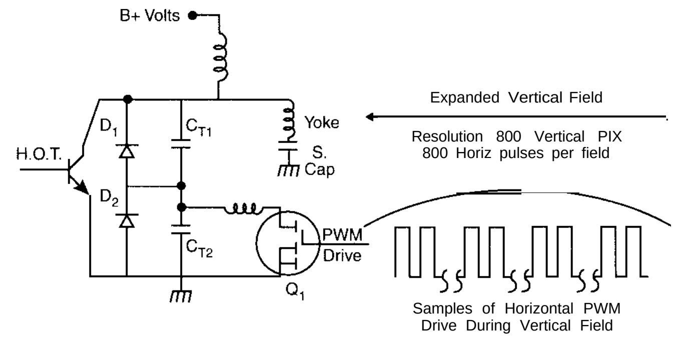


Fig. 6: Pincushion correction by varying the duty cycle of a switching FET during each horizontal cycle, changing the division of voltage between Ct1 and Ct2.

Another method of correcting pincushion distortion is to vary the B+ voltage to the deflection output stage at a vertical rate. Figure 7 shows how the vertical pincushion correction waveform can be applied to the pulse width modulator along with the feedback and microprocessor width control inputs. The PWM control IC outputs a PWM drive signal that varies in pulse width according to the pincushion voltage waveform. The B+ voltage to the deflection horizontal output stage increases and decreases to produce the needed pincushion deflection width changes during the vertical field.

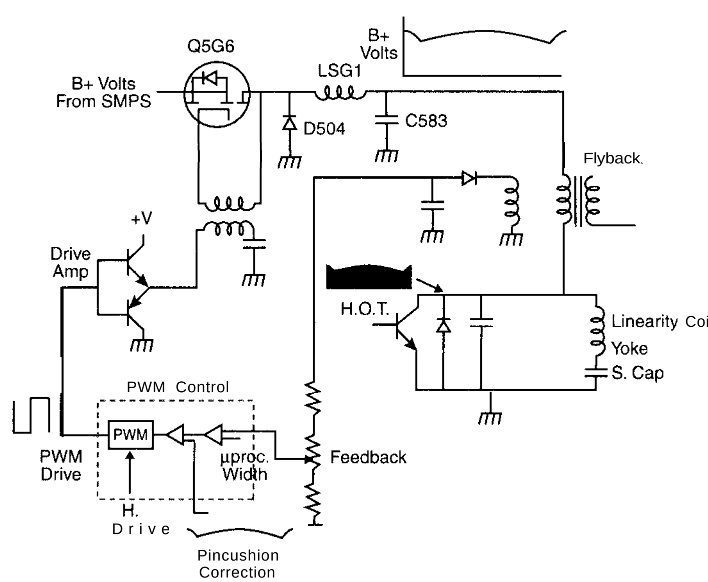


Fig. 7: Pincushion correction by varying the B+ voltage at a vertical correction rate.

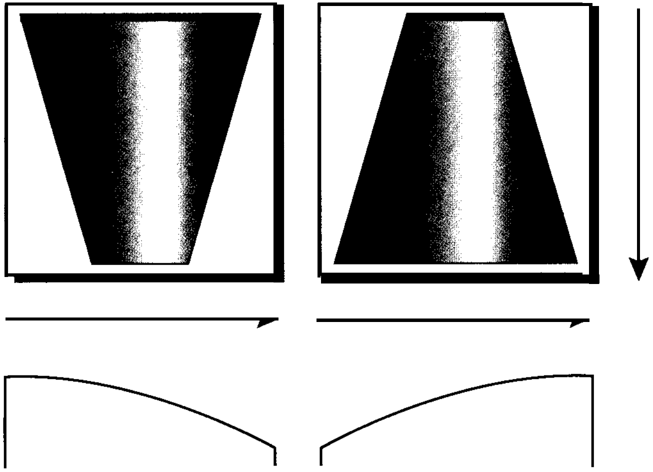


Fig. 8: A trapezoid correction waveform may be added to the pincushion waveform for trapezoid adjustment during the vertical field.

Trapezoid Horizontal Deflection Control

Many multi-frequency monitors have additional user controls that affect horizontal deflection. One such user control that adjusts picture width from the top to the bottom of the display is the trapezoid adjustment. This adjustment is commonly performed with a correction waveform as is pincushion correction. A trapezoid correction waveform, like a pincushion waveform, originates from the vertical circuit and is shaped by special amplifiers. The waveform is added to the pincushion waveform and applied to the horizontal deflection circuits with one of the methods described. The waveform varies the deflection width as the vertical field is produced.

Additional horizontal deflection related user adjustments may be done by adding voltage waveforms to the pincushion correction waveform. The phase of correction waveforms are often shifted with respect to the vertical and horizontal scan times for additional picture deflection control.