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tech tips

Understanding and Testing TV Vertical Yokes

How the Vertical Yoke Produces CRT Beam Deflection

Understanding vertical stages requires an understanding of cathode ray tube (CRT) beam deflection. Inside the CRT, an electron gun emits a stream of electrons. These electrons travel to the face of the CRT, striking the phosphor surface to produce light.

In video display CRTs, a magnetic field is produced by the vertical coils of a yoke mounted around the neck of the CRT. The yoke is constructed with coils wound around a magnetic core material. When current flows in the vertical yoke coils, a magnetic field is produced. The yoke's core concentrates the magnetic field inward through the neck of the CRT. As the electrons pass through the magnetic field on the way to the CRT face, they are "deflected" or pulled upward or downward by the yoke. This causes the electrons to strike the CRT face at points above or below the center.

The direction of the current in the yoke coil determines the polarity of the yoke's magnetic field. This determines if the electron beam is deflected upward or downward. Current flow in the direction shown in Fig. 1A causes the electron beam to deflect upward. Current flow in the opposite direction through the yoke coils (Fig. 1B) reverses the magnetic field causing the beam to deflect downward.

A requirement of vertical deflection in a TV or monitor is that the current in the coils of the vertical yoke increase an equal amount for specific time intervals. This linear current change causes the deflection of the electron beam to make a uniform or smooth movement from the top to center and from the center to the bottom of the CRT face.

How the Vertical Drive Signal is Produced

The vertical section consists of four basic circuits or blocks as shown in Fig. 2. They include 1) Oscillator or Digital Divider, 2) Buffer/Predriver Amp, 3) Driver Amp, and 4) Output Amplifier. The circuitry for these stages may be discrete components on the circuit board or may be included as part of an integrated circuit(s).

The vertical oscillator generates the vertical signal. The signal is output to the amplifiers and drives the yoke to produce deflection.

The output of a vertical oscillator must be a sawtooth shaped waveform. A ramp generator is often used to shape the output waveform of a freerunning generator switches a transistor on and off, alternately charging and discharging a capacitor. When the transistor is off, the capacitor charges to the supply voltage through a resistor. When the transistor is switched on, the capacitor is discharged.

The vertical oscillator must be synchronized with the video signal so a stationary picture can be viewed on the CRT display. The oscillator frequency is controlled in two ways. A vertical hold control may be used to set the free-running oscillator close to the vertical frequency. Vertical sync pulses, removed from the video signal, are applied to the vertical oscillator, locking it to the proper frequency and phase. If the oscillator is not synced, the CRT picture rolls vertically. The picture rolls upward when the oscillator frequency is too low, and downward when the frequency is too high.

There are several intermediate amplifier stages between the output of the vertical oscillator and output amplifier stage. Some common stages are the "buffer", "predriver" and/or "driver". The purpose of the buffer amplifier stage is to prevent loading of the oscillator which may cause frequency instability or waveshape changes.

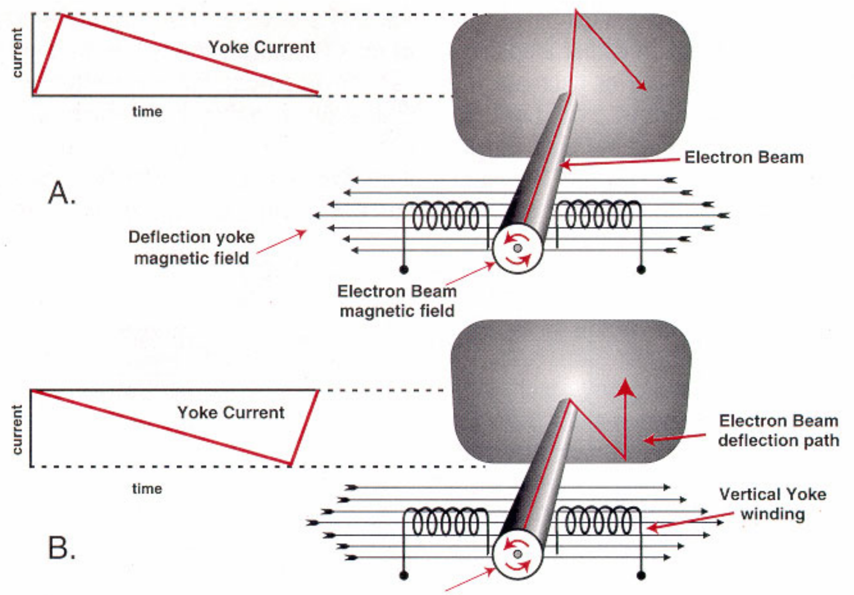

Fig. 1: The yoke mounted on the CRT neck produces the magnetic field, resulting in electron direction.

The predriver and/or driver stages shape and amplify the signal to provide sufficient base drive current to the output amplifier stage. This permits the output stage transistors to produce the yoke current needed for full and linear deflection.

The predriver and/or driver amplifier stages are commonly DC coupled and use AC and DC feedback much like audio amplifier stages. Feedbak maintains the proper DC bias and waveshape to insure the current drive to the yoke remains constant a components, temperature, and power supply voltages drift.

AC feedback in most vertical circuits is obtained by a voltage waveform derived from a resistor placed in series with the yoke. The small resistor is typically placed from one side of the yoke to ground. A sawtooth waveform is developed across the resistor as yoke current alternates through it. This resistor provides feedback to widen the frequency response, reduce distortion, and stabilize the output current drive to the yoke. The feedback is often adjusted with gain or shaping controls known as the Vertical Height or Size and Vertical Linearity controls.

DC feedback is used to stabilize the DC voltages in the vertical output amplifiers. DC voltage from the output amplifier stage is used as feedback to an earlier amplifier stage. Any slight increase or decrease in the balance of the output amplfiers is offset by slightly changing the bias. Since the amplifiers are direct coupled, the bias change slightly shifts the bias on the output transistors bringing the stage back into balance.

How the Vertical Output Stage Produces Yoke Current

The vertical yoke may require up to 500 mA of alternating current to produce full deflection. A power output stage is required to produce this level of current.

A vertical output stage commonly consists of a complementary symmetry circuit with two matched power transistors (see Fig. 3). The transistors conduct alternately in a push-pull fashion. The top transistor conducts to produce current in one direction to scan the top half of the picture. The bottom transistor conducts to produce current in the opposite direction to scan the bottom of the picture.

To better understand the typical vertical output stage, we will analyze the current paths at four times during the vertical cycle (refer to Fig. 3). Starting with time “a”, the top transistor, Qt, is turned on by the drive signal to its base. The transistor is biased “on” resulting in a low conduction resistance from collector to emitter which provides a high level of collector current. This puts a high +V potential at the top of the yoke resulting in a fast rising current.

During time “a”, capacitor Cs charges toward +V and current flows through the yoke and the top transistor, Qt. This pulls the CRT’s electron beam from the center of the CRT quickly to the top. During time “a”, an oscilloscope connected at the emitter junction displays a voltage peak as shown in the V Output waveform. The inductive voltage from the fast changing current in the yoke along with retrace “speedup” components cause the voltage peak to be higher than +V.

The current flowing in the yoke during time “a” produces a waveform as viewed from the bottom of the yoke to ground. This is the voltage drop across Rs which is a reflection of the current flowing through the yoke.

During time “b”, the drive signal to Qt slowly increases the transistor’s emitter to collector resistance. Current in the yoke steadily decreases as the transistor increases its E-C resistance and reduces its collector current. The voltage at the emitter junction falls during this time and capacitor Cs discharges. A decreasing current through the yoke causes the CRT’s electron beam to move from the top to the center of the screen.

To produce a linear fall in current through the yoke during time “b” demands a critically shaped drive waveform to the base of Qt to meet its linear transistor operating characteristics. The drive waveform must decrease the transistor’s base current at a constant rate. Furthermore, the transistor must operate with linear base-to-collector current characteristics. Reductions in base current must result in proportional changes in collector current. The linear decrease in the yoke current is shown by the I Yoke or Vrs waveform.

At the end of time “b”, transistor Qt’s emitter-to-collector resistance is high and the transistor is approaching the same emitter-to-collector resistance as the bottom transistor Qb. The capacitor Cs has been slowly discharging to the falling voltage at the emitter junction of the output transistors. Just as the voltage at the emitter junction approaches ½ +V, the bottom transistor begins to be biased “on” to begin time “c”. This transition requires that the conduction of Qt and Qb at this point be balanced to avoid distortion in the center of the CRT.

During time “c”, the resistance from the collector to emitter of transistor Qb is slowly decreased by the base drive signal and the collector current increased. Capacitor Cs begins to discharge, producing current through the yoke and through Qb. As Qb’s resistance decreases and its collector current increases, the voltage at the emitter junction decreases. This can be seen on the V Output waveform as it goes from ½

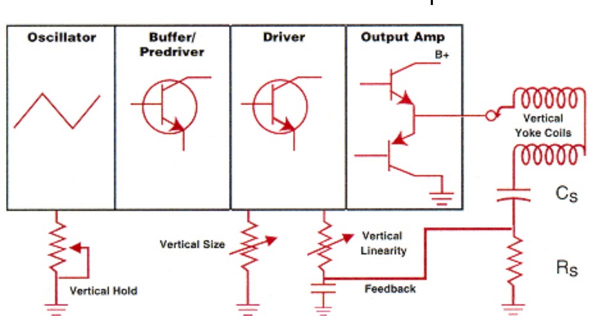

Fig. 2: The vertical section of a TV consists of an oscillator, buffer, driver, and output amplifier.

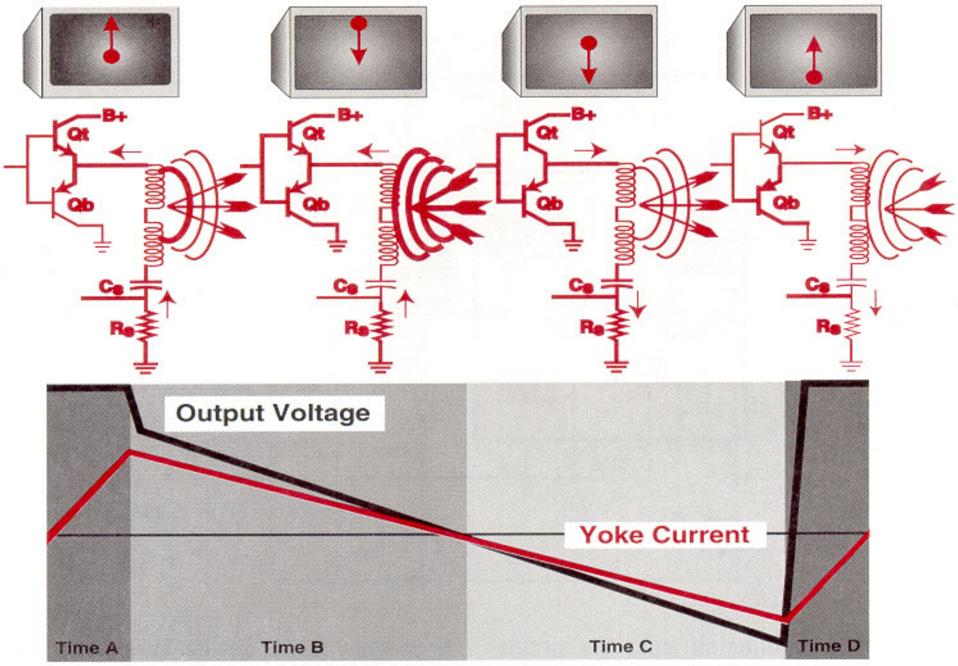

Fig. 3: The deflection, currents, and waveforms during four periods of vertical cycle.

+V towards ground during time "c". The current increases at a linear rate through the yoke, as shown in the I Yoke or Vrs waveform.

The resistance decrease of Qb must be the mirror opposite of transistor Qt's during time "b". If not, the yoke current would be different in amplitude and/or rate causing a difference in CRT beam deflection between the top trace and bottom trace times. At the end of time "c", the emitter to collector resistance of Qb is low and the current in the yoke approaches a maximum level.

At the start of time "d", the emitter to collector resistance of Qb is increased quickly and collector current decreased. This quickly slows the discharging current from capacitor Cs through the yoke and transistor. As the current is reduced, the trace is pulled quickly from the bottom back to the center. Time "a" begins once again, and the cycle repeats.

Understanding Today's Vertical ICs

Most of the vertical stages discussed in this Tech Tip are found in today's television receivers as parts of one or two integrated circuits. Of course, the yoke and other components external to the IC are required so the IC's individual vertical stages work properly. Let's look at the operation of a typical IC vertical circuit found in the NAP R1 TV chassis.

The vertical oscillator in this chassis is a vertical countdown stage within the TV Signal Processor IC (see Fig. 4). The vertical countdown block receives an input from the horizontal oscillator, divides it by 262, and is gated by vertical sync. The output is a synchronized vertical pulse on pin 27.

The vertical signal is buffered by a transistor and applied simultaneously to the microprocessor and character generator to synchronize on-screen display graphics. The signal is also routed to pin 3 of IC550. IC550 contains a ramp generator, buffer amplifier, and the vertical amplifier stage.

The vertical signal to the ramp generator charges and discharges C558, producing a sawtooth or ramp signal at pin 7. The amplitude of the ramp signal is adjustable with the vertical size control. The lack of an input to the ramp generator would result in no output and no vertical yoke deflection.

The output of the ramp generator feeds the buffer amplifier and then the output amplifier at pin 9. DC voltage at pin 9, developed by the voltage divider networks, sets the bias to the amplifier and provides the DC feedback to stabilize the gain of the amplifier and center the deflection.

The output amp of IC550 contains the complementary output amplifier transistor stage as explained in this Tech Tip. The output amplifier causes current to alternate through the yoke by conduction through the parallel resistors R568 and R569 charging and discharging capacitor C565. During retrace time, the flyback generator block switches-in capacitor C553, which was charged to 28 volts during trace time. The capacitor and D550 conduct, doubling the supply voltage to the output, producing a waveform amplitude of 58 volts peak during retrace at pin 1. The added voltage works to increase the rate of current and speed up retrace time.

A portion of the signal across the yoke series capacitor, C565, is shaped by R563/C567 and added to the DC at pin 9. This AC feedback shapes the drive signal and maintains proper drive linearity. Problems associated with IC550 or components surrounding it all can cause reduced or improper deflection due to the DC and AC signal feedback. A quick method to accurately prove the yoke is good at full operational current lets you know the circuit has a relatively inexpensive part causing the problem.

Understanding the TVA92's Vertical Yoke Drive Output

The TVA92 TV Video Analyzer dynamically tests the vertical yoke by subbing for the drive signal, which normally drives the yoke. This lets you analyze the yoke's ability to produce a full linear deflection.

The TVA92's Vertical Yoke Drive Output signal is produced by circuits similar to the vertical stages of a TV receiver. Vertical sync pulses originating in the TVA92's video generator are input to the TVA92's vertical ramp generator to sync lock the yoke drive. Since the Vertical Yoke Drive signal is locked to the video, you can simply watch the CRT of the receiver to determine if the vertical yoke coils produce proper vertical deflection.

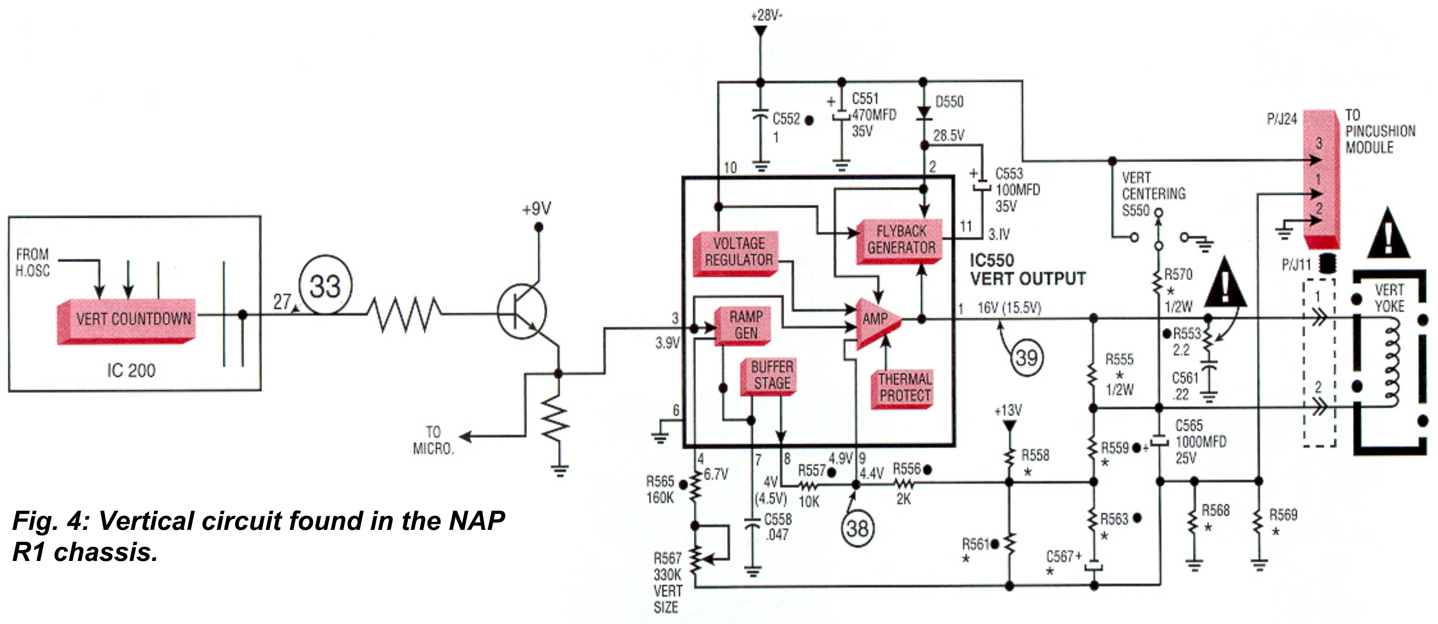

Fig. 4: Vertical circuit found in the NAP R1 chassis.

The TVA92's Vertical Yoke Drive Level control lets you increase the output signal (AC current) to the yoke being tested. The control varies the output from approximately 0-40 VPP and deflection current from 0-1.5 amp peak. When the TVA92's Output Signal Monitor DVM switch is set to "Yoke Drive", the digital LCD display indicates the output peak-to-peak signal level.

Connecting the TVA92 to the Vertical Yoke

The TVA92 Vertical Yoke Drive signal is present on a separate jack – a jack different than the other TVA92 substitution signals. The Vertical Yoke Drive is unlike the other TVA92 substitution signals, so it is applied to the circuit differently.

The vertical output amplifier in a TV receiver is a power output amplifier. It drives current into a low impedance load (yoke). Attempting to swamp out the output current drive of the amplifier and substituting for it at the same time would not be effective and would likely cause component damage. Therefore the yoke must be disconnected from the circuit before applying the TVA92's Vertical Yoke Drive.

There are two ways to disconnect the vertical yoke from the circuit. The easiest is simply to remove the plug that connects the vertical yoke to the circuit board. You may find a single plug connecting the vertical and horizontal yoke to the circuit board or separate vertical and horizontal plugs. Another method of disconnecting the yoke is unsoldering the wires from the yoke windings. Most yokes have mounted terminals on the yoke assembly that can be accessed by removing a plastic cover.

How to Test the Vertical Yoke with the TVA92

To test the vertical yoke, start with the TVA92 Vertical Yoke Drive control set to "0" and the Output Signal Monitor/DVM switch set to "Yoke Drive." Connect the VG91 or VA62A RF/IF Output to the antenna input on the TV receiver. Set the VG91 or VA62's RF-IF controls to generate a cable channel at 1000 uV. Select the "Crosshatch" video pattern.

Now apply power to the TV chassis and turn it on. Select the channel on the TV receiver to agree with the number of the RF channel indicated by the VG91 or VA62. Observe the CRT of the receiver for an illuminated horizontal line across the middle of the screen.

Increase the Vertical Yoke Drive Level control while looking at the CRT. Adjust the control in either the positive or negative direction until the Crosshatch pattern nears the top and bottom of the display. If the vertical yoke is good, you will see a full and near-linear deflection. The Crosshatch pattern boxes should be near squares from the top to the bottom of the screen if the yoke is good.

If the yoke is bad, the results will be similar to the problem seen when the chassis vertical circuits are driving the yoke. To achieve full deflection may require an increase in the TVA92 drive level control resulting in foldovers or nonlinearities in the Crosshatch video pattern seen on the display.