

## AUTOMATIC ALIGNMENT TECHNIQUES FOR COLOR TELEVISION MANUFACTURING

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### INTRODUCTION

The need to remain competitive in the consumer market requires every producer of color television to continually reduce costs of manufacturing. Reducing the cost of components is the most obvious solution, but other areas now receiving increased attention are those of reduced assembly and test labor, and increased yield through quality enhancement. Automating the final alignment of a color television receiver is a concept that is presented here. The procedure discussed will result in faster alignment time, less labor costs, and more alignment repeatability.

### RECEIVER DESIGN CRITERIA

The concept proposed requires that the receiver be designed to accommodate the technique (Figure 1). A new series of integrated circuits are now available which provide control of the customer settings and the CRT geometry via a serial bus. Registers internal to the various components of the system store digital values which are converted by internal DACs to analog control voltages and currents. All of the registers may be modified by using a single MCU interfaced to the serial bus. Furthermore, a remote control receiver is available which also interfaces to the control bus.

Channel selection is accomplished via the serial bus by sending the appropriate codes to the PLL. This sets the band switch and programmable divider to the required values. The audio level is also controlled via the serial bus, utilizing the special stereo sound decoder/audio processor IC.

The main component of the system, a Video/Timebase Processor Integrated Circuit<sup>1</sup>, is a complete, highly integrated luma/chroma/deflection system with all necessary filters incorporated in silicon (Figure 2). The majority of the registers which are accessed for the final alignment are incorporated on this one IC.

As an introduction to the parameters which will be adjusted, the various control registers within the device are reviewed (Figure 3). Each of the registers store 6 bits of information. The registers may be divided into 3 categories: CRT drive, customer adjustment, and CRT geometry.

← 6 BITS →
VERTICAL AMPLITUDE
VERTICAL BREATHING CORRECTION
PARABOLA AMPLITUDE
PARABOLA TILT
VERTICAL LINEARITY
VERTICAL POSITION
HORIZONTAL AMPLITUDE
HORIZONTAL BREATHING CORRECTION
GRID 2 VOLTAGE
HORIZONTAL PHASE CONTROL
BLUE RELATIVE INTENSITY
GREEN RELATIVE INTENSITY
RED RELATIVE INTENSITY
CONTRAST
BRIGHTNESS
SATURATION
HUE

Figure 3. Video Processor IC Control Registers

There are 4 registers associated with the CRT drive: the G2 voltage control and the R, G, and B relative intensity controls. These will be set for the correct screen control and white balance. There are also 4 customer control registers in the video processor IC: contrast, brightness, color saturation and hue.

### CRT GEOMETRY CONTROL

Registers 1-8 and 10 control the geometry characteristics of the CRT. These registers provide complete control over the CRT, perhaps beyond what is commonly performed in U.S. manufacturing today. Vertical amplitude,

<sup>1</sup>Chroma 4 Video/Timebase Processor, and M44000 Advanced TV System

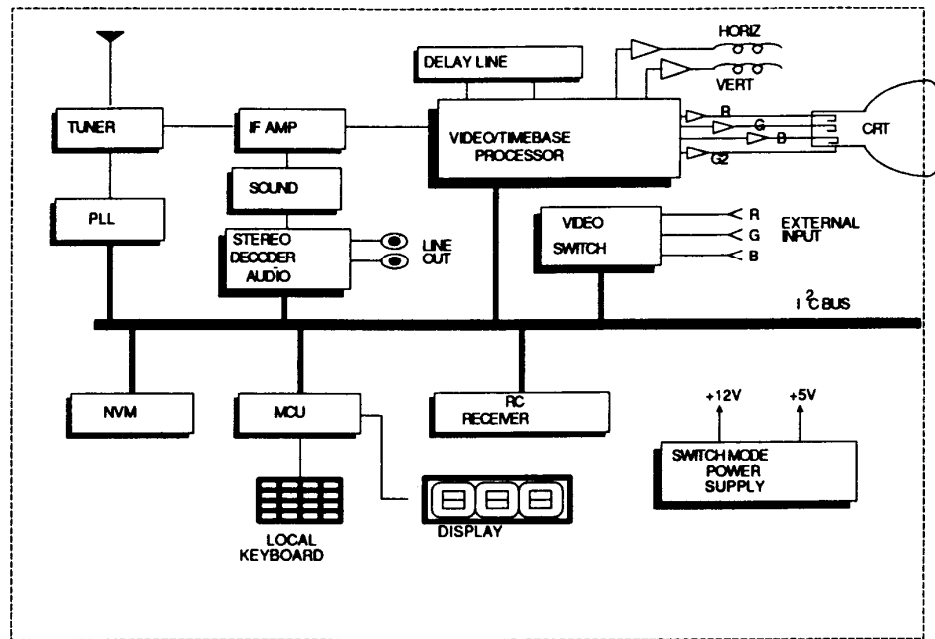


Figure 1. Typical Advanced Color TV System

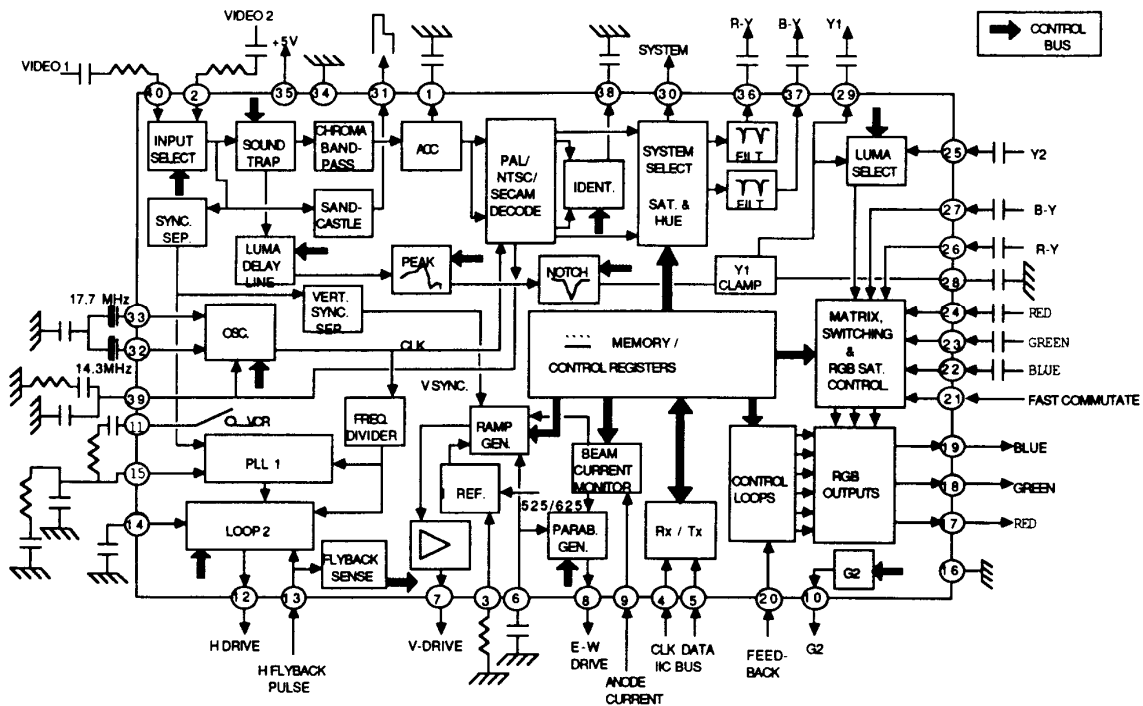


Figure 2. Video/Timebase Integrated Circuit Block Diagram

position, and linearity are obvious, but the terminology of some of the other adjustments may not be familiar to those who do not perform deflection design.

Horizontal amplitude is often called width control, and the horizontal phase control is the horizontal positioning or centering.

Parabola amplitude and tilt are used to correct what might otherwise be called pincushion effect. A rectangular test signal on a receiver with poor parabolic adjustment might appear as in Figure 4. The parabola amplitude adjustment

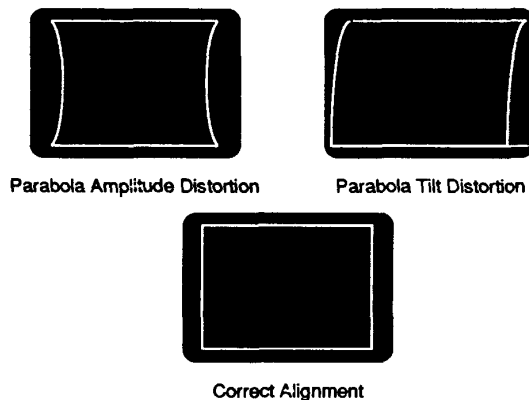


Figure 4. Parabola Amplitude and Tilt

corrects the deviation from the top or bottom to the center of the screen, while the parabola tilt adjusts the top and bottom horizontal offset for equalization.

Vertical and horizontal breathing refers to the respective variations in height and width due to changes in the average beam current (Figure 5).

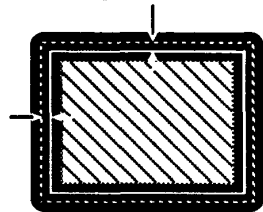


Figure 5. Horizontal and Vertical Breathing

This would appear as a broader or taller raster during bright scenes, due to reduction of the high voltage.

## ALIGNMENT TECHNIQUE

Providing electronic control to all of the parameters discussed above is the key element in developing an automated final test alignment system. The proposed solution utilizes a color video camera to monitor the CRT of the receiver under test. The advantage of using a video camera over photo-detectors placed at various locations on the CRT are listed below.

First, there is no physical contact required to the CRT, as in the case of attaching a fixture to the CRT faceplate. The camera can be fixed in a stationary position on the side of the assembly line, awaiting the arrival of the next receiver.

Next, the camera is the only feedback element needed, rather than multiple fixtures with photo-diodes for various tests and alignments.

The camera provides high video resolution to perform the alignment. In fact, the camera can provide more precise alignment than that attainable through manual adjustment.

Various screen sizes may be aligned using a single test station. By adjusting the zoom on the camera, a full raster may be obtained for the full range of sets produced.

The proposed automated alignment system is shown in Figure 6. The video camera presents separate R, G, B and sync signals. The camera must be calibrated to provide specific levels of R, G, and B for a "standard" white color temperature. This permits each manufacturer to specify the white balance desired.

Control of the receiver under test is transferred to an external "alignment" computer via a connector on the back of the receiver. This connector would also be useful for providing in-home service alignment without necessity to remove the back of the receiver.

A variety of test patterns are generated and made available on different channels within the test facility. Since the tuning PLL divider is also controlled via the serial bus, any test pattern may be selected automatically by choosing the

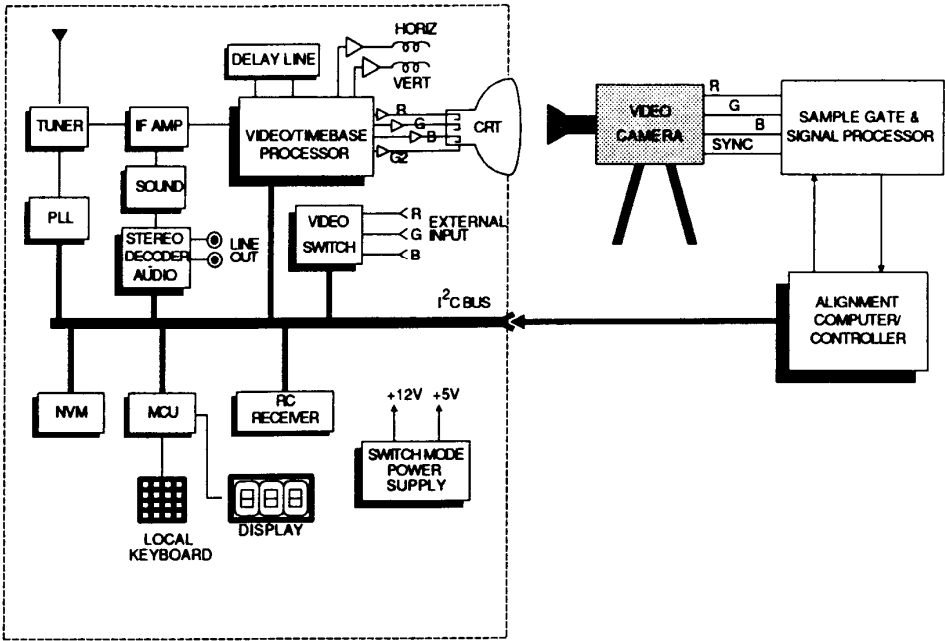


Figure 6. Color TV Automatic Alignment System

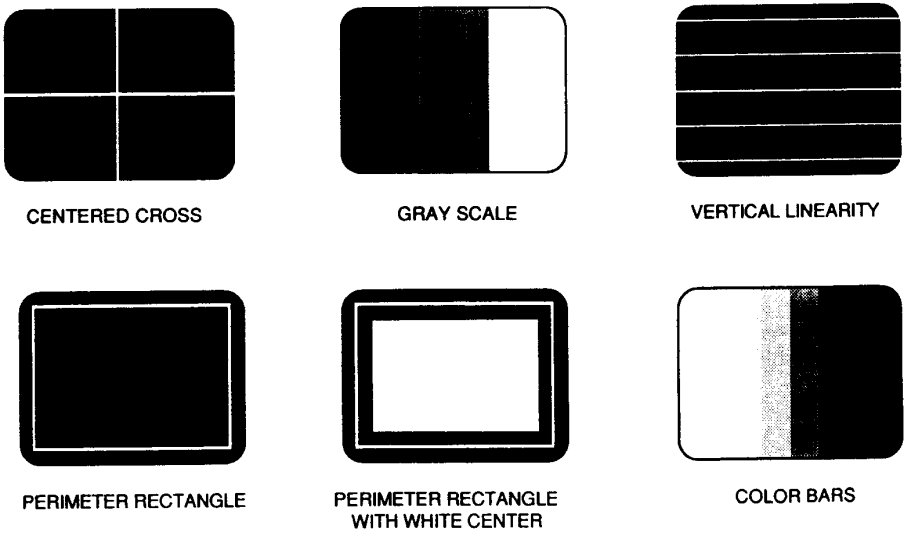


Figure 7. Test Patterns

appropriate channel via the alignment controller.

All of the test signal generators, and the video camera are locked together in sync. The signals derived from the red, green, and blue outputs of the video camera are each sampled at specific times relative to horizontal and vertical sync. By applying each of a series of test signals, the outputs of the video camera may be monitored, and appropriate changes made to the receiver's internal registers to modify the results on the CRT as needed.

The test patterns that will be used are shown in Figure 7. These consist of a (1) centered cross, (2) gray scale stair step, (3) vertical linearity, (4) black raster with a perimeter rectangle (5) black raster with perimeter rectangle and a center section which periodically alternates between black and white, and (6) standard color bars.

#### ALIGNMENT PROCEDURE

(see Chart 1)

The first step in the alignment procedure is initializing certain registers in the video processor IC. The alignment controller initializes the receiver with a preliminary setup of minimum saturation, mid-brightness and mid-contrast, mid R, G, and B relative intensities.

The first alignments are for the CRT screens and drives. The G2 voltage is first adjusted for cutoff using the gray scale stair step test pattern. The G2 register is adjusted until some level of luminance is detected in the first step of the pattern; then reduced until the camera video output monitors black during this step. The steps are wide enough such that position and width mis-adjustments may be ignored.

Next, the gray scale is adjusted. The gray scale stair step test pattern again is used. The outputs of each of the R, G, and B outputs of the camera are sampled on the center bar of the CRT. This is designated as midway between horizontal sync pulses on a horizontal line midway between vertical sync pulses. Comparing each of the amplitudes with their respective stored reference values which were

determined during camera "standardization", an exact mixture of R, G, and B can be obtained by adjusting each of the relative intensity registers in the video processor IC. It may be noted that this technique of adjusting gray scale is independent of convergence alignment, since the red, green and blue scan lines are observed independently.

The horizontal and vertical positions are adjusted next. The centered cross test pattern channel is selected. The video output from only one color gun is monitored for the remainder of the CRT parameter adjustments. For correct alignment, the signal for the horizontal bar of the cross should occur on the horizontal line midway between vertical sync pulses. By detecting which line contains the target video, the vertical position register of the video processor IC can be adjusted until the correct scan line contains the "cross" video. This may be accomplished by counting video lines from the end of vertical sync until the signal representing the horizontal line of the cross is detected. The delta between actual and reference location on the screen is fed back to the vertical position register. In a similar fashion, the horizontal position can be determined by sampling the camera video signal and measuring the delay from horizontal sync to the video pulse which represents the vertical line of the cross. Any deviation of pulse from mid-point results in modification of the data in the horizontal phase register until the correct horizontal position is obtained.

The horizontal and vertical amplitudes are adjusted next by again selecting the perimeter rectangle test pattern. The delay of the white perimeter video pulse from the horizontal sync pulse is adjusted with the appropriate register until the desired scan amplitude is attained. Likewise, the vertical line in which the top of the perimeter white video signal occurs is adjusted via the vertical position register for the desired result.

The vertical linearity can be adjusted by using the standard cross hatch signal, although a pattern with 5 evenly spaced horizontal lines is adequate. The scan lines in which these lines appear are monitored and the vertical linearity register is adjusted until the 5 lines fall within a prescribed window of acceptability. It should be

recognized than perfect linearity may be unattainable and a variation of plus or minus several scan lines for positioning of each of the test pattern lines should be acceptable.

Horizontal and vertical breathing, and parabola amplitude and tilt are often not adjusted in receivers manufactured in the U. S., since their effects may be held to a minimum with appropriate deflection components; however, the video processor IC provides adjustment of these characteristics for those manufacturers who desire to use it. The breathing adjustments compensate for deflection variations caused by high beam current. A dynamic test signal which consists of a perimeter rectangle and a periodically alternating black and white center is used to force the average beam current to transit extremes. The location of the horizontal and vertical sides of the perimeter are monitored with the black center, and the respective breathing registers are adjusted for minimum change in position when the white center is displayed.

The parabola amplitude and tilt adjustments are performed using the perimeter rectangle test pattern. The relative delay from horizontal sync to the left edge of the perimeter is monitored near the top, middle and bottom of the screen. The tilt register is adjusted for equal delays at the top and bottom reference points. Once this equalization is attained, the parabola amplitude register is adjusted for equal delays between the top (and bottom) and the center reference.

At this point, convergence may be aligned. At present, this must still be performed manually, but the possibility of developing special devices to provide bus controllable adjustments to this parameter is being considered.

The customer controls will next be adjusted. Contrast and brightness are adjusted using the gray scale pattern. The brightness (black-level) register is adjusted until some value of luminance is detected in the first step, then reduced until "black" is monitored. The contrast register is set to monitor a "standardized" value of white level on the last (third) step.

The standard color bar test pattern is used for

the hue and saturation adjustment. The saturation register is raised to mid-point, and samples of the R, G, and B camera outputs are taken at the magenta and cyan bars. These are chosen as the sample points since the balance of these two colors generally provides the best color reproduction. The values for the 3 outputs are processed by the alignment controller to determine the effective color angle. The hue register is adjusted until the correct proportions of the colors are attained.

Finally, the red camera output is sampled during the red bar, and the saturation register is adjusted until a preset reference level is observed.

### CONCLUSION

A technique has been proposed to automatically align a color television designed with a new family of integrated circuits which incorporate internal control registers which may be set via a serial bus. By using a video camera as the feedback element, a fast, accurate alignment of nearly all of the parameters adjusted in final test may be obtained.

It should be noted that as the various geometry adjustments are made, the output levels from the video camera will change amplitude. This is due to the camera scan lines not coinciding

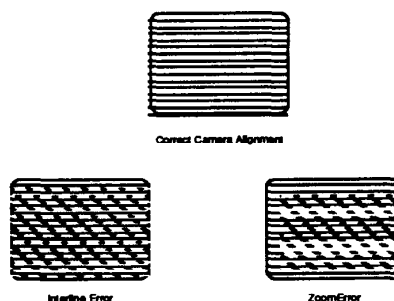


Figure 8. Camera Alignment Parameters

with the respective CRT scan lines, as shown in Figure 8. A possible solution for this phenomena is to control the zooming of the camera lens system, and finely adjusting the zoom for maximum video signal after each alignment step. De-focusing the camera slightly for these alignments may also provide a solution for the amplitude dependent parameters.

Chart 1. Alignment Parameters

Screen & Drive Alignment				
Screens	<u>Test Pattern</u> Gray Scale	<u>Monitor</u> Video level at first step on any of video outputs	<u>Adjust Register</u> Grid 2 Voltage	<u>For</u> Detectable luminance, then black level
Drives	Gray Scale	All three video outputs on center step	R,G,B Relative Intensity	Match to reference amplitude
Horizontal & Vertical Position				
Horizontal	<u>Test Pattern</u> Centered Cross	<u>Monitor</u> Delay of white video pulse from sync pulse	<u>Adjust Register</u> Horizontal Phase	<u>For</u> 1/2 Active Line delay
Vertical	Centered Cross	Vertical Line on which horizontal cross occurs	Vertical Position	Center Vertical Line
Horizontal & Vertical Amplitude				
Horizontal	<u>Test Pattern</u> Perimeter Rectangle	<u>Monitor</u> Left edge of perimeter near center vertical line	<u>Adjust Register</u> Horizontal Amplitude	<u>For</u> Reference Delay from Horizontal Sync
Vertical	Perimeter Rectangle	Top edge of perimeter near center of horizontal	Vertical Position	Reference vertical line below vertical sync
Vertical Linearity				
	<u>Test Pattern</u> Linearity	<u>Monitor</u> Vertical lines on which video signal occurs	<u>Adjust Register</u> Vertical Linearity	<u>For</u> All 5 lines are within acceptable range
Horizontal & Vertical Breathing				
Horizontal	<u>Test Pattern</u> Alternating black/ white perimeter rectangle	<u>Monitor</u> Left edge of perimeter near center vertical line	<u>Adjust Register</u> Horizontal Breathing Correction	<u>For</u> Minimum variation as test signal alternates from from black to white.
Vertical	Alternating black/ white perimeter rectangle	Top edge of perimeter near center vertical line	Vertical Breathing Correction	Minimum variation as test signal alternates from from black to white.
Parabola Amplitude and Tilt				
Tilt	<u>Test Pattern</u> Perimeter rectangle	<u>Monitor</u> Delay of left edge from sync near top and bottom	<u>Adjust Register</u> Parabola Tilt	<u>For</u> Equal delay from horizontal sync.
Amplitude	Perimeter rectangle	Delay of left edge from sync near top and center	Parabola Amplitude	Equal delay from horizontal sync.

**Contrast and Brightness**

Brightness	<u>Test Pattern</u> Gray Scale	<u>Monitor</u> Video Level at first step on any video output	<u>Adjust Register</u> Brightness	<u>For</u> Detectable luminance, then black level
Contrast	Gray Scale	Video Level at last step on any video output	Contrast	Match to reference amplitude

**Hue and Saturation**

Hue	<u>Test Pattern</u> Color Bars	<u>Monitor</u> R, G, and B outputs at magenta & cyan bar	<u>Adjust Register</u> Hue	<u>For</u> Reference ratio of R:G:B
Saturation	Color Bars	R output during red bar	Saturation	Match to reference amplitude

**BIOGRAPHY**

Leonard Suckle received his BSEE from Drexel Institute of Technology in 1966. He is currently Strategic Marketing Manager for the Consumer Segment of Motorola Semiconductor Products Sector. In his 12 years at Motorola, he has served in a variety of marketing and systems design engineering positions within the Strategic Marketing organization. Prior to joining Motorola he was a design engineer in color TV systems for Magnavox and Philco-Ford, and an integrated circuit process and circuit design engineer for Philco Ford and RCA. He has several publications, and holds a patent in speech synthesis.