APPENDIX C
CIE-UCS Chromaticity Coordinates

Color Temp Kelvin	CIE 1931 Chromaticity Coordinates		CIE 1976 UCS Chromaticity Coordinates	
	x	y	u′	v′
Black Body Values				
3000	0.4369	0.4041	0.2482	0.5214
3500	0.4053	0.3907	0.2347	0.5113
4000	0.3804	0.3768	0.2249	0.5016
4500	0.3608	0.3635	0.2175	0.4927
5000	0.3451	0.3516	0.2118	0.4847
5500	0.3324	0.3410	0.2074	0.4775
6000	0.3221	0.3318	0.2039	0.4712
6500	0.3135	0.3236	0.2011	0.4655
7000	0.3064	0.3165	0.1988	0.4605
7500	0.3003	0.3103	0.1969	0.4561
8000	0.2952	0.3048	0.1952	0.4521
8500	0.2908	0.2999	0.1939	0.4486
9000	0.2869	0.2956	0.1927	0.4454
9300	0.2849	0.2932	0.1921	0.4436
9500	0.2836	0.2917	0.1917	0.4425
10000	0.2806	0.2883	0.1908	0.4399
10500	0.2780	0.2852	0.1900	0.4375
11000	0.2757	0.2824	0.1894	0.4354
11500	0.2736	0.2799	0.1888	0.4334
12000	0.2718	0.2776	0.1882	0.4317
CIE Standard Illuminants				
D50	0.3457	0.3586	0.2100	0.4881
E	0.3333	0.3333	0.2105	0.4737
D55	0.3320	0.3480	0.2049	0.4810
D65	0.3127	0.3290	0.1989	0.4683
C	0.3101	0.3162	0.2013	0.4609
D75	0.2990	0.3149	0.1945	0.4585

u' = 4x / -2x + 12y + 3

v' = 9y / -2x +12y + 3

CP5000

All Display Color Analyzer System

with the

ColorPro III and ColorPro IV

Operation and Application Manual

Standard Serial
or
USB

SENCORE
3200 Sencore Drive, Sioux Falls, SD 57107

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APPENDIX B

White Balance Adjustment Procedure

Following is a general white balance (gray scale, color temperature) display adjustment procedure that will produce a properly adjusted display in most cases. If a service manual is available for the display, however, use the manufacturer's adjustment procedure.

White Balance Adjustment

1. Select, in the Setup Utility window, the CIE chromaticity coordinates/color temperature to which the display is to be adjusted.
   Note: *Most displays should be adjusted to the CIE D65 daylight standard (x = 0.313, y = 0.329) for best color match with standard program material.*

2. Adjust the brightness control to make blacks just black (use the Pluge pattern, or use the pluge bars in the Window pattern) and adjust the contrast control for maximum brightness without blooming or raster distortion (use the Needle pattern).
   Note: *If starting from scratch after a CRT or other video component replacement, preset the display's drive (gain) controls for maximum brightness and the cutoff (bias) controls for minimum brightness.*

3. Select a Window pattern and adjust the pattern level for a low IRE level to produce approximately 1-2 Ft-Lamberts of luminance in the center of the white window, as measured with the CP5000. If a low IRE pattern isn't available, use a 100 IRE pattern and adjust the contrast control to produce approximately 1-2 Ft-Lamberts of luminance in the center of the white window or white raster pattern.

4. Leaving the cutoff control for the initially strongest color (as viewed on the dim CRT) at its original or preset level, adjust the other two cutoff controls to obtain color balance at the desired chromaticity coordinates.
   Note: *The CP5000 Delta RGB display indicates which is the strongest and weakest color.*

5. Select a Window pattern and adjust the pattern level for 80-100 IRE, or adjust the contrast control to produce high brightness without blooming. Most direct view displays will track well up to 100 IRE, whereas many projection displays produce a better compromise tracking when adjusted at a lower IRE level.

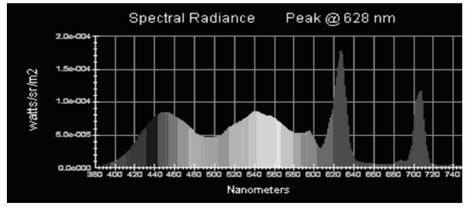
6. Leaving the drive control for the initially weakest color (as viewed on the bright CRT) at its original or preset level, adjust the other two drive controls to again obtain color balance at the desired chromaticity coordinates.
   Note: *If only two drive controls are available, select the color that is missing as your adjustment reference color in the Delta RGB display.*

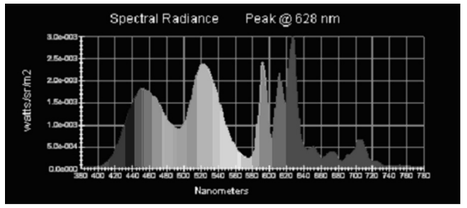
7. Re-select the low luminance Window pattern or readjust the contrast control to produce approximately 1-2 footlamberts of luminance and recheck/readjust the cutoff controls for the desired chromaticity coordinates.

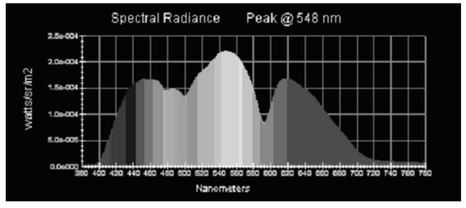
8. Repeat steps 3-7 until the display's chromaticity coordinate remains relatively constant (tracks) over the full range of IRE levels or contrast control adjustment.

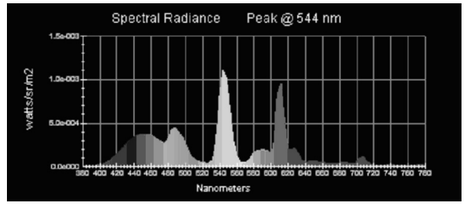
Final User Control Adjustment

When the white balance adjustment is complete, perform a final adjustment of the display's user controls (brightness, contrast, sharpness, color, and hue).









This means that, if a colorimeter is to produce accurate measurement results for all display types, its optical filters must accurately duplicate the CIE standard observer response at all color frequencies, not just at the particular frequencies at which CRTs produce high light output. Its three color sensors must see light over the entire visible spectrum with the exact same amplitude response that the three color sensors of our eye see light.

The CP5000 'ColorPro' All-Display Color Analyzer System uses optical filters which are accurate to the CIE standard observer response at all frequencies of light, not just high output CRT frequencies, and accurately measures all displays of the past, present, and future.

DESCRIPTION

Introduction

Video displays have rapidly become a standard fixture in our world. They are used in applications from home theaters, to video arcades, personal computers, hospital imaging displays, broadcast studios, etc. Sencore developed the CP5000 ColorPro All Display Color Analyzer System to help manufacturers, installers, and service centers accurately measure and perform white balance calibration on all types of displays.

The CP5000 All Display Color Analyzer System consists of two precision color-analyzing light measurement sensors and the CP5000 ColorPro application software. This system can be used for color analysis on all types of video displays, providing fast, accurate measurements, allowing you to confidently test and calibrate these displays for proper gray scale tracking. The ColorPro III measurement sensor measures all direct view and projection displays, with the exception of LCD flat panel (direct-view) displays. The ColorPro IV measurement sensor measures LCD flat panel displays.

Features

- Accurately measure and perform white balance calibration on all types of direct-view and projection displays, including CRT, Plasma, DLP, LCD, D-ILA, etc.
- Specifications traceable to NIST standards.
- The CP5000 ColorPro application software simultaneously displays measured data in numeric format, and in 1931 CIE and Delta RGB graphs, both referenced to a desired white reference.
- Numeric display indicates 1931 xy chromaticity coordinates, Y luminance units (user-selectable as either Foot Lamberts or Candela/m^2 (nits)), color temperature Kelvin units, and delta chromaticity error (ΔE_{xy}).
- The CIE Chromaticity graph, with selectable axis resolution, shows exactly how different the measured color is from the desired white reference color, and shows the direction of the color error.
- The Delta RGB display, with individual red, green, and blue plus/minus graphs, allows you to see exactly which colors need to be adjusted to obtain a desired white reference color, and also gives you a quick visual “pass/fail” indicator of the color performance of the display under test.
- Dark Calibration feature optimizes measurement accuracy at low light levels.
- Selectable White Reference color target coordinates allow you to calibrate to any standard color, plus capture, save, or recall any number of custom White References.
- The Report feature allows you to capture and save pre-calibration and post-calibration display performance data and print a display calibration report for documentation.
- You can also track the performance of the display by using the “Record” feature, which prints single or continuous measured data to a text data file.

Specifications

General

Display Modes: 1931 CIE xyY
Delta RGB bar graphs of variance from White Reference
CIE xy chromaticity graph of variance from White Reference
Color Temperature in Kelvins
Delta E_{xy} chromaticity variance from White Reference
Luminance units are selectable as either footlamberts or cd/m^2 (nits).

White References: Six CIE Standard Illuminant (D65, D50, E, D55, D75, C) and twenty one black body color temperature white references (3000K to 12000K in 500K steps) are pre-loaded. Custom white chromaticity references can be manually input or captured from a display measurement. An unlimited number of custom white references can be saved to disk for later recall.

Measurement Update Rate/Averaging: Adjustable
Host System: Pentium-class CPU running Windows 95 or better.
Operating Temperature: 10 to 25°C
Operating Relative Humidity: 10 – 80% (non-condensing)
Operating Altitude: Sea level to 10,000 ft.
Accuracy Specifications: @ 20°C, relative to NIST-certified reference at D65

ColorPro III

Accuracy: xy: ± 0.002
(@ 65 cd/m2 minimum) Y: ± 2%
Repeatability: xy: ± 0.002
(same-sensor/no-dismount) Y: ± 1%
Luminance Range: 0.05 – 800 cd/m^2 (0.02 - 233 fL)

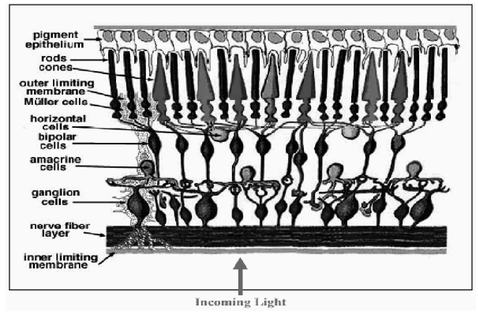
ColorPro IV

Accuracy: xy: ± 0.004
(@ 65 cd/m2 minimum) Y: ± 2%
Repeatability: xy: ± 0.002
(same-sensor/no-dismount) Y: ± 1%
Luminance Range: 3 – 350 cd/m^2 (0.9 - 102 fL)
Sensor Field of View: 10°

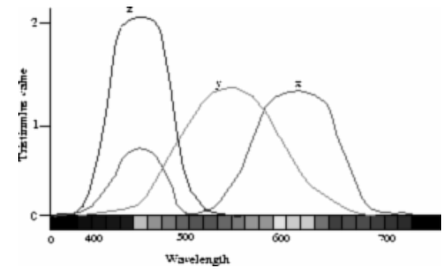
APPENDIX A

Measuring Light as the Eye Sees Light

The human eye sees light through rod and cone type light receptors. There are red, green, and blue cone type receptors, while the rod receptors give us black and white vision, especially in small detail and low light.



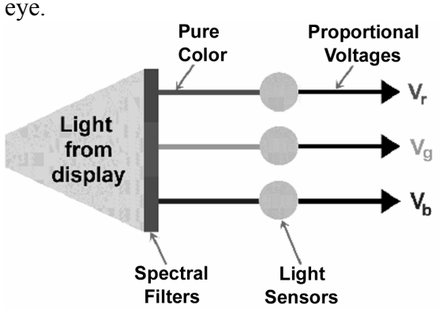
The red, green, and blue cone receptors each have a different response to different colors (frequencies) of light. The average response of the human eye receptors to light across the visible spectrum is shown by the Standard Observer Response graph, developed by the International Commision on Illumination (CIE).



We call this tristimulus vision, as there are three types of receptors that individually send information to our brain and allow us to perceive different colors for the different mixtures of light energy within the visible spectrum.

Tristimulus Measuring Devices

Tristimulus color measurement devices are called colorimeters. This type of device works much the same as the human eye. A filter for each light sensor allows only a precise amount of each color of light to reach the sensor from the source to be measured. The response of each of the three filters is designed to mimic the response of one of the three types of cones in the average human eye.



The measurement information from each of the three light sensors allows us to compute a different measurement result for the different mixtures of light energy within the visible spectrum, in a way that duplicates the response of the human eye/brain combination. To accurately predict the response of the human eye to a combination of light energy at different frequencies, a tristimulus color measurement device must "see" light exactly the same way the human eye sees light.

Display Technology Changes

Display types that are now on the market produce spectrums of light that are often very different from each other and from the average spectrum produced by CRTs. Some displays produce strong peaks of light at color frequencies where CRTs produce much less light. The mixing results of these color frequencies still give us the familiar red, green, and blue that CRTs produce, but start with different levels of some color frequencies. The important difference between these new display types and the older CRT technology is that new technology displays may produce strong peaks of light at just about any color frequency.

Tips for using the ColorPro

Ambient Light
The ColorPro is extremely sensitive to ambient light. When you calibrate a front projection or rear projection type display, be sure to remove any room light. Ambient light will be measured along with light produced by the display, and will cause inaccurate readings.

If room light cannot be removed when calibrating a rear projection display, some type of shroud may need to be used to block light from the face of the display. If room light reaches the front glass, it will enter the cabinet, be internally reflected, and come back out of the display, affecting the ColorPro readings.

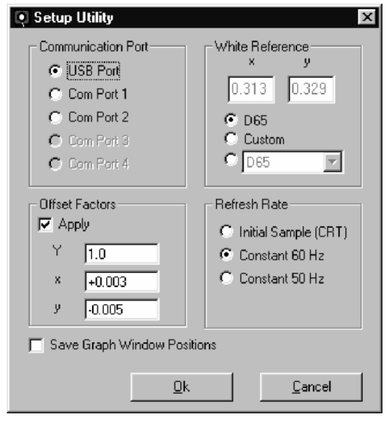
Sensor Attachment
Make certain the ColorPro sensor adheres to the face of the display and stays attached during color measurements. The color coordinates will change dramatically if the sensor changes position.

Sensor Cleaning
To be sure that the ColorPro sensor remains attached to the face of the display, be sure that both the face of the display and the suction cup surfaces are free from dirt and grime. Use a paper towel, moistened with liquid glass cleaner, to clean the rubber suction cup surfaces and the face of the display. Alternately, use pre-packaged alcohol-moistened prep pads.
Note: *Do not use cleaning solutions other than liquid glass cleaner or isopropyl alcohol. Also, do not apply the cleaner directly to the sensor, only to the paper towel.*

Measuring a Front Projector
When measuring a front projector, place the ColorPro III sensor at the middle of the screen, with the diffuser and suction cups pointed at the projector, away from the screen. The ColorPro holder accessory can be mounted to the top of a video tripod to hold the sensor in this position.

Most newer screens are close to neutral and do not significantly affect the color of the reflected light. If desired, this can be checked, however. Hold the sensor about an inch or two from the screen, pointed at the screen, but at about a 45 degree angle to the screen so that the sensor is able to see light reflected from the screen, and not its own shadow. When you are at the right distance and angle, the readings should not change significantly as the sensor is rotated a quarter turn.

If the screen introduces a chromaticity offset to the x, y readings, you can enter the screen offsets into the CP5000 program and make the calibration more conveniently with the sensor pointed at the projector. For example, if the screen measures 0.003 higher in x and 0.005 lower in y than the projector directly, enter those offsets in the Setup Utility window, as shown below. Then, check the Apply box to apply the offset to your measurements.



CP5000 ColorPro System

Supplied Items

ColorPro III color analyzer sensor.
ColorPro IV color analyzer sensor.
Software Installation CD-ROM.

CH51a – Color Pro holder that connects to a standard video tripod for use with rear or front projection displays

EC58 – 25 ft serial extension cable for the ColorPro that aids in aligning large displays and video walls.

or

39G1016 – 10 ft USB extension cable for the ColorPro that aids in aligning large displays and video walls.

Brushed aluminum, custom-fitted carry case.

Operate the ColorPro

Installing the CP5000 ColorPro Software

The installation program will guide you through the process of installing the CP5000 software in Windows.

1. Insert the CP5000 installation CD into the CD-ROM drive. The setup window should appear automatically to guide you through installation. If the setup window does not appear automatically, continue with step 2. Otherwise, skip to step 4, or follow the on-screen instructions.
2. In Windows 95 or higher, click **Start**, **Run**, and **Browse**.
3. Execute the file **setup.exe** located on the CD-ROM.
4. Choose the destination drive and directory or click **OK** to use the CP5000s default drive and directory.
5. Follow the instructions on your screen. Click **Next** to continue through the setup process.
6. When the software has completed loading, click **Finish** and remove the CD from your drive.

Installing the CP5000 ColorPro Hardware

The ColorPro III and ColorPro IV measurement sensors are available with either standard serial (DB9) or USB connectors. A standard serial sensor connects directly to a serial port on your PC. You can specify COM 1, 2, 3, or 4 in the CP5000 software Setup Utility. A USB sensor connects to a USB port on your PC. The CP5000 software automatically detects a ColorPro sensor connection to any USB port on the PC. Only one USB sensor can be connected to the PC at one time.

Installing the USB hardware driver

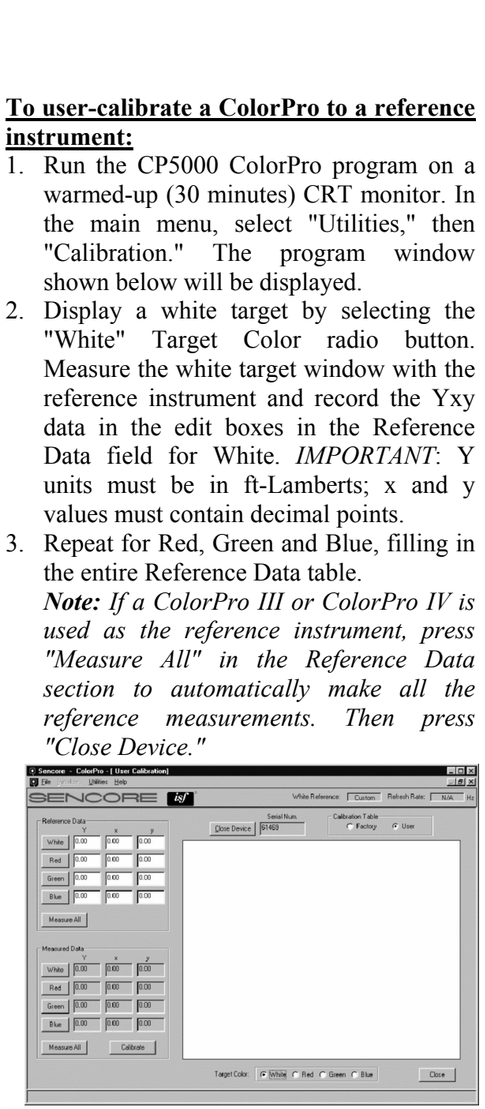
The first time you connect a USB ColorPro sensor to your PC USB port, Microsoft Windows® will recognize it as new hardware and will initiate a search for the device driver software (or, you can initiate the search by selecting “Add New Hardware” in Control Panel).

When you are asked whether the device that you want to install is listed, reply No.

When asked whether you want Windows to search for your new hardware, specify that you want to select the hardware from a list.

To user-calibrate a ColorPro to a reference instrument:

1. Run the CP5000 ColorPro program on a warmed-up (30 minutes) CRT monitor. In the main menu, select "Utilities," then "Calibration." The program window shown below will be displayed.
2. Display a white target by selecting the "White" Target Color radio button. Measure the white target window with the reference instrument and record the Yxy data in the edit boxes in the Reference Data field for White. *IMPORTANT*: Y units must be in ft-Lamberts; x and y values must contain decimal points.
3. Repeat for Red, Green and Blue, filling in the entire Reference Data table.
   Note: *If a ColorPro III or ColorPro IV is used as the reference instrument, press "Measure All" in the Reference Data section to automatically make all the reference measurements. Then press "Close Device."*



The Calibration utility allows you to calibrate a CP5000 sensor to a reference device.

4. Attach the ColorPro sensor to to be calibrated to your computer com or USB port (if required, change the port under "Utilities/Setup" and press "Open Device."
5. Save the current ColorPro calibration, if desired, for the sensor to be calibrated (see "Save Calibration Data," below). This will allow you to later restore the original calibration data to this probe.
6. Attach the ColorPro probe to the computer monitor CRT over the target window.
7. Press the "Measure All" button in the Measured Data section. The program automatically displays each of the color targets and measures with the ColorPro.
8. Press the "Calibrate" button. The program automatically displays each of the color targets, calculates new calibration data, and writes the data to the ColorPro probe.
9. The ColorPro is ready to use with its new calibration and can be tested by pressing the "Measure All" button in the Measured Data section again.
10. Press the "Close Device" button and attach the next ColorPro probe to be calibrated to the reference instrument, or press "Close" to exit the Calibration utility.

Additional calibrations may be created for a ColorPro by using the following two functions. These allow calibration data to be saved to a file and restored to a ColorPro from a file.

Save Calibration Data

1. Select "File" then "Save Cal to File" from the main menu bar.
2. Enter a file name and extension describing the ColorPro and calibration type (including the pod serial number as part of the file name is helpful).
3. Press the "Save" button and the file is created in the chosen directory. Note: This function always saves calibration data directly from the currently connected sensor, regardless of what measurement data is displayed on the Calibration window.

Restore Calibration Data

1. Select "File" then "Restore Cal to Sensor" from the main menu bar.
2. Enter the file name of the calibration data file.
3. Press the "Open" button and the ColorPro's User calibration data is updated.

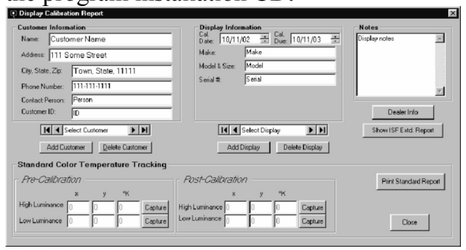
Display Calibration Report

Clicking the Report button on the Main Measurement Window opens the Display Calibration Report window.

- Customer Information – this section allows you to record customer contact information and a customer identification number (e.g. invoice number).
- Display information – this section allows you to record information about the display, including the calibration due date.
- Standard Color Temperature Tracking – this section allows you to capture pre-calibration and post-calibration data to be printed in a graphical format.

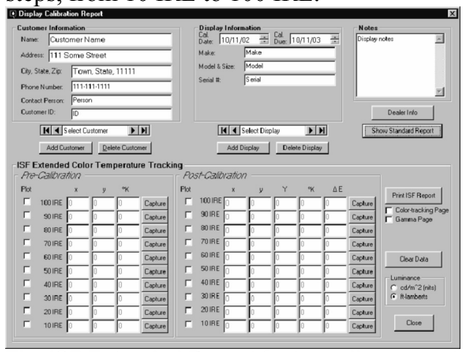
Information entered in the Report form is automatically saved in the program installation directory as an Access database file called:
ColorProCustomerDatabase.mdb.

Report information saved in the CP288 ColorPro program can be imported into the CP5000 report database by running the database convert utility DataConvert.exe, on the program installation CD.



The Standard Report feature allows you to store and print a calibration report for a customer.

Show ISF Extd Report – allows you to switch to an expanded report for to capture pre-calibration and post-calibration data in 10 IRE steps, from 10 IRE to 100 IRE.



The ISF Extended Report feature allows you to store and print an extended three page calibration report for a customer.

Calibration Utility

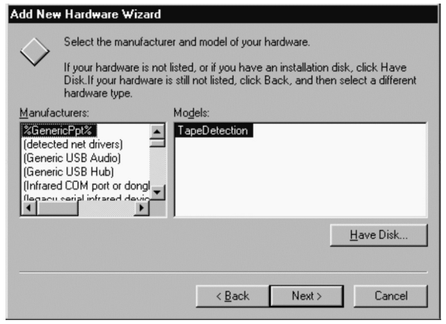
The ColorPro color analyzers are capable of being end-user calibrated to match another reference instrument, using the Calibration utility included in the CP5000 ColorPro program. The original factory calibration is not over-written, and can be restored.

Calibration Data Stored in a ColorPro

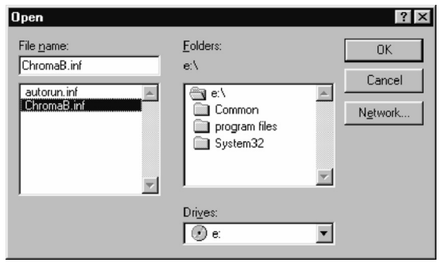
There are two sets of calibration data (tables) stored in a ColorPro, named "Factory" and "User." Factory calibration data is the original calibration data programmed at the factory and cannot be field modified. User calibration data can be modified by an end-user. Both calibration tables are stored in the ColorPro's non-volatile memory. The ColorPro sensor defaults to using the Factory calibration data, unless User data is present.

Under "Hardware Types" select "Other Device."

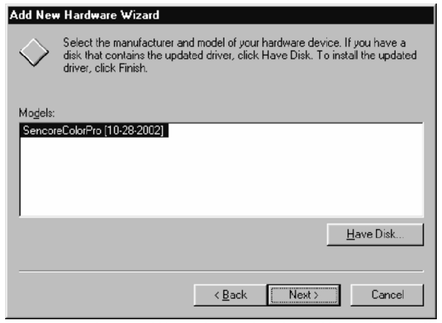
When asked to select the manufacturer and model of your hardware, specify that you "Have Disk.



In the File Open dialog that opens, browse to the root directory of the CP5000 installation CD, and select the SenColPro.inf device driver file.



If the installation CD is not immediately available, the driver file is also located in the directory in which you installed the CP5000 software (default C:\Program Files\Sencore\ ColorPro5000\USB Drivers).



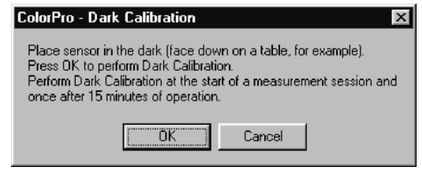
Accept the calibration device listed, to finish installation of the device driver.

Running the CP5000 Software

When you have completed the installation, double-click the ColorPro 5000 shortcut icon on your PC desktop. When the attached ColorPro sensor initializes, the Dark Calibration dialog will appear. Place the sensor in the dark (face down on a flat surface, or against your clothing, for example). Then, click the OK button in the dialog box.

ColorPro Dark Calibration dialog

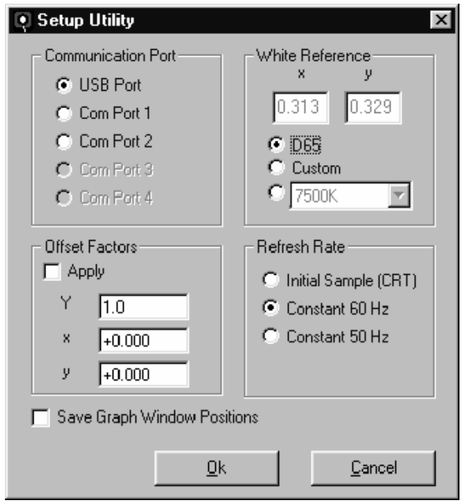
A ding sound will alert you when the dark calibration is complete, at which point you are free to move the sensor, and the initialization process will complete.



The first time the CP5000 software is run, the Setup Utility window will be displayed when the sensor initialization is complete.

ColorPro Setup Utility window

The Setup Utility allows you to define the default settings for the CP5000. These selections are the default settings for which the CP5000 will be configured whenever the program is run. You may change these selections at any time by selecting "Setup" from the "Utilities" item on the main menu bar.

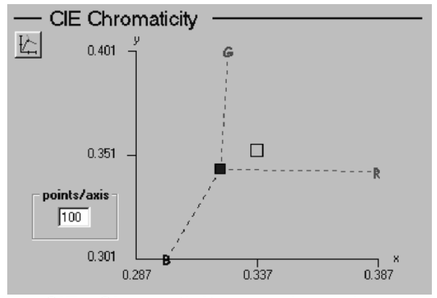


- **Communication Port** - this section allows you to select USB Port, or Com Port 1, 2, 3, or 4 as the port to which the ColorPro sensor will be connected. A Com port selection will not be enabled if the port is not installed.

- **White Reference** - this section allows you to select the chromaticity coordinates to which you wish to calibrate your display. You can select the video industry standard D65, enter your own custom xy chromaticity coordinates, or select one of 27 CIE standard illuminants or black body color temperature coordinates.

- **Offset Factors** - this section allows you to apply fixed offsets to the luminance and chrominance measurements you perform. The Y Offset Factor is a multiplication offset (an entry of 2.0 would cause the displayed luminance values to be twice their normal values). The x and y Offset Factors are additive offsets (an entry of +0.002 for x would cause the displayed x chromaticity value to be 0.002 higher than its normal value). The entered offset values affect the displayed measurements only when the "Apply" box is checked.

- **Refresh Rate** - this selection gives you the option of selecting either Initial Sample, Constant 60Hz, or Constant 50Hz as the method the ColorPro uses for locking to the display refresh rate.
  - **Initial Sample** causes the CP5000 to make an initial sample of the light refresh rate when the measurement is started, and then will make measurements at that refresh rate. Make sure that you are sampling a bright white raster (50 IRE or higher) on the display when you first start the measurement. This option should be selected when you measure a CRT direct-view, CRT rear- projection, or CRT front-projection display. ***Note:*** *If you change the display's format refresh rate, the ColorPro should be stopped and restarted so the new refresh rate can be sync locked too. Failure to do this may result in inaccurate luminance readings because the sensor may be taking readings during the blanking time.*
  - **Constant 60Hz** causes the CP5000 to make measurements at a 60Hz fixed rate. This option should be selected when you measure any non-CRT type display, whether a direct-view or projection type display. This includes plasma, LCD, DLP, D-ILA, etc. type displays. This option can also be used for any CRT display operating at a 60Hz refresh rate format (e.g. NTSC or 60 Hz computer monitor formats).
  - **Constant 50Hz** causes the CP5000 to make measurements at a 50Hz fixed rate. This setting can be used for PAL displays.



The CIE Chromaticity graph makes color alignments easier to perform by graphically plotting the x, y readings.

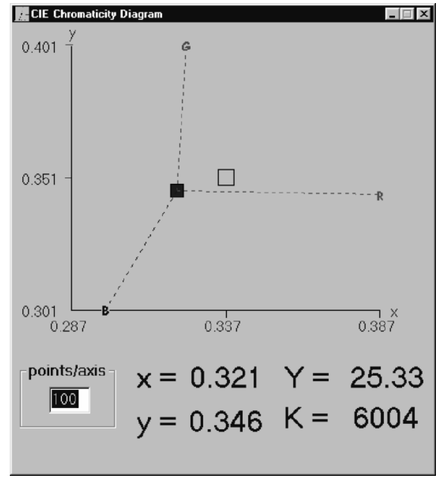
The color of the measurement cursor reflects the state of the measurement, as follows:

- **Red** indicates the measured value is outside the graph range.
- **Blue** indicates the measured value is inside the graph range.
- **Green** indicates the measured value is exactly the same as the reference.

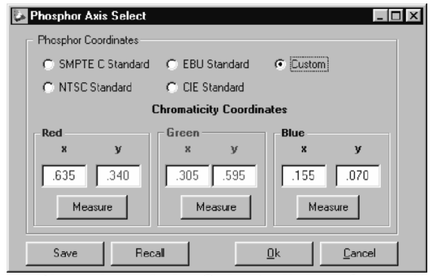
The **points/axis** feature lets you set the graph resolution, in the range of 4-400 **points/axis**. To change the setting, click in the box, and type the new value.

To view a larger, separate CIE Chromaticity display window, click the CIE Chromaticity icon, just below the CIE Chromaticity section title. This window allows you to better view the results of display adjustments from a distance.

The measurement cursor is connected to R, G, and B phosphor indicators with dotted "steering" lines. This feature shows the direction the measurement cursor will travel if individual colors are adjusted on the display being measured. Example: If blue is increased, the measurement cursor will travel towards the blue phosphor indicator, along the path of the blue dotted line. If blue is decreased, the cursor will travel away from the blue phosphor indicator.



Clicking on one of the CIE Chromaticity display phosphor indicators opens the Phosphor Axis Select dialog.



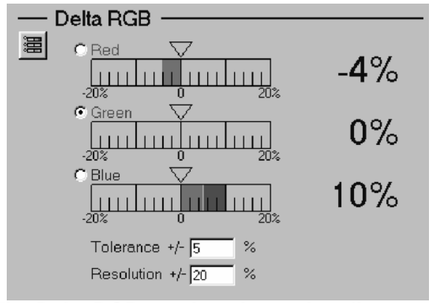
The Phosphor Axis Select dialog for setting the CIE Chromaticity display RGB indicator positions.

The Phosphor Axis Select dialog sets the positions of the CIE Chromaticity display RGB indicators to more accurately match the phosphors of the display under test, to minimize red, green, and blue control interaction. This setting does not affect the accuracy of the measurement, but may simplify the alignment.

At the right end of the tool bar, above the Start button, is the Refresh Rate indicator. This shows the refresh rate which has been automatically detected (Initial Sample), or which has been manually selected (Constant 60 or Constant 50). When the ColorPro IV is being run, the display will show "N/A", as the ColorPro IV uses measurement technology which doesn't need to be synchronized to a display's refresh rate.

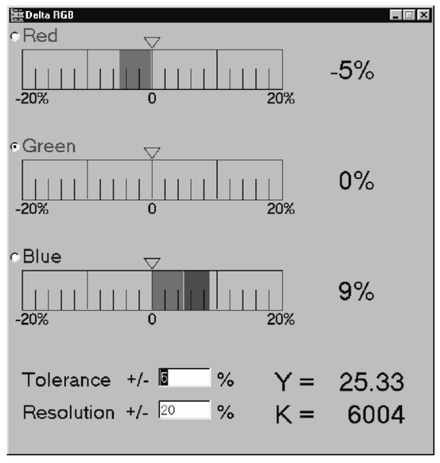
Delta RGB Graph

The Delta RGB graph, in the lower left corner of the ColorPro measurement window, displays red, green, and blue color values in a bar graph format to assist in calibrating a display to a particular white reference. The triangle and 0 at the center of each bar graph is the adjustment target. Adjusting the bar graphs all to the center target balances the light output color of the display under test to the selected White Reference.



The Delta RGB graph makes color alignments easier to perform by graphically plotting individual red, green and blue levels, with one color selected as an adjustment reference. In the example shown, Green is the chosen adjustment reference, Red is 4% below balance, and Blue is 10% above balance.

To view a larger, separate Delta RGB graph window, click the Delta RGB icon, just below the Delta RGB section title. This window allows you to better view the results of display adjustments from a distance.



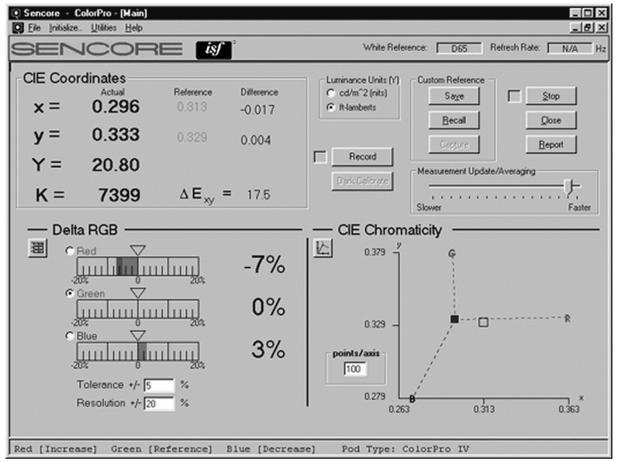
When using the Delta RGB graph to make a calibration adjustment, one of the three colors is selected as the adjustment reference and the remaining two colors are adjusted to balance with the level of that reference color. Click the white circle that corresponds with the desired adjustment reference color.

CIE Chromaticity Graph

The CIE Chromaticity display, in the lower right corner of the ColorPro measurement window, displays the measured x, y chromaticity coordinates in the 1931 CIE chromaticity diagram, to assist in calibrating a display to a particular white reference. The colored measurement cursor on the graph represents the actual measured coordinates. The small open box in the center of the graph is the selected White Reference coordinate target.

Main Measurement Window

CP5000 Measurement Window



The **Measurement Window** is displayed when you boot up the CP5000. From here you can quickly access any of the CP5000 features.

Across the top of the window is the Menu Bar. Accessing the features on the Menu Bar can be done either by clicking on the selection with your mouse or by pressing ALT and the corresponding underlined letter simultaneously.

Click on:

- **File** to expose a pull down window for exiting the CP5000.
- **Initialize** to initialize the ColorPro sensor attached the communications port selected in the Setup Ulility, then brings up the ColorPro Control Panel shown above. This window will come up only if the Color Pro sensor is connected to the selected communications port.
- **Utilities** to allow you to choose the Setup Utility or the Calibration Utility.
- **Help** to bring up the Help menu.

Selecting Measurement Sensors

ColorPro III

The ColorPro III sensor, the thinner sensor with a milk-white diffuser glass, should be used to measure all front-projectors (e.g. CRT, LCD, DLP, D-ILA), rear-project (e.g. CRT, LCD, DLP), and direct-view displays (e.g. CRT, Plasma) - but not LCD flat panel displays.

ColorPro IV

The ColorPro IV sensor, the thicker sensor with four light tubes, should be used to measure all LCD flat panel displays. The restricted light acceptance angle of the ColorPro IV sensor, due to the light tubes leading back to the color sensors, allows the sensor to properly integrate the light emitted from a LCD flat panel. Since an LCD flat panel produces light with a restricted emission angle (similar to an automotive headlight), a sensor with a wide angle integrating diffuser cannot accurately integrate the panel's luminance output. Plus, the chromaticity readings will be inaccurate with a wide angle sensor. The ColorPro IV sensor reads luminance and chromaticity accurately for all LCD flat panel displays.

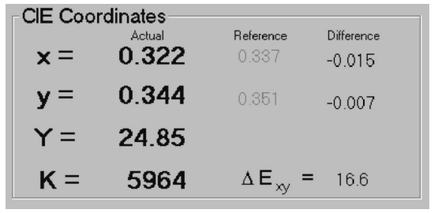
Making Color Measurements

To begin making color measurements, press the **Start** button at the upper right of the main window. The Start button is re-labeled as Stop, and all measurement fields become active with updating measurements.

When the color sensor is taking measurements, the box just to the left of the Start button alternates between green and gray. The box remains solid gray when the sensor is not taking measurements.

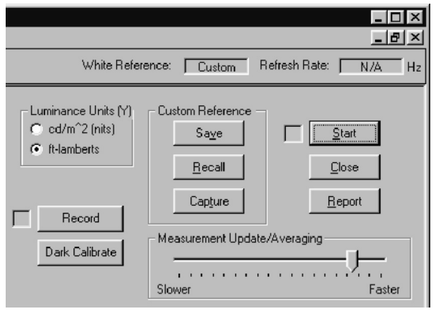
To stop making color measurements, press the **Stop** button. The button is re-labeled as Start, and all measurement fields become frozen with the last active measurement.

Measurement Window Features



CP5000 Measurement Window CIE Coordinates section

- In the **CIE Coordinates** section, the large blue numbers on the left display the current readings (labeled **Actual**).
  - The **x** and **y** values are the 1931 CIE chromaticity coordinates of the measured light.
  - The **Y** value is the luminance value of the measured light.
  - The **K** value is the Correlated Color Temperature of the measured light.
  - The **Reference** values are the chromaticity coordinates selected in the White Reference section of the Setup Utility.
  - The **Difference** values are the numeric difference between the reference and actual readings.
  - The ΔE_{xy} value is the delta color error of the measured x, y coordinates, compared to the reference coordinates. This number is derived by the hypotenuse value of the x, y difference, multiplied by 1000. Example – If the x difference is 0.003, and the y difference is 0.004, the x, y hypotenuse would be 0.005. Multiplied by 1000, this gives a ΔE_{xy} value of 5.



CP5000 Measurement Window Controls section

- **Luminance Units** - selectable between **foot-lamberts** and **cd/m^2 (nits)** by clicking the white button. A black dot identifies the currently selected luminance unit.

- **Custom Reference** – allows you to **Capture**, **Save**, or **Recall** custom white reference data. The desired White Reference is selected in the Setup Utility window and the current White Reference selection is indicated on the tool bar, just above the Custom Reference section. If Custom white reference is selected, the **Custom Reference** controls are active.

To save custom white reference data, click the **Save** button. A "Create ColorPro Reference File" dialog will appear, prompting you to enter a filename and storage location. Click the **OK** button when you have finished.

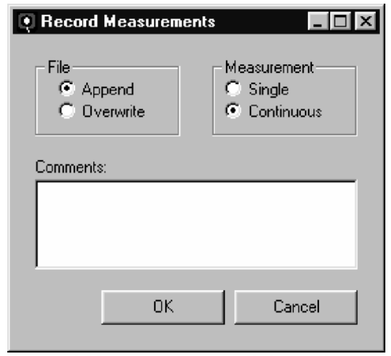
  - To recall a saved custom white reference, click the Recall button. A list of stored references will be displayed. Highlight the reference you wish to load and click the OK button.
  - To change the reference to the actual measured data, click the Capture button. This button is enabled only when you have selected "Custom" as the White Reference in the Setup Utilities menu. This is useful when you have a display aligned to the exact coordinates you want (possibly a customer's custom requirements etc.). You can measure the chromaticity of the "target" display and capture the coordinates so you can save the reference for future alignments.

- **Start/Stop** button - allows you to start or stop measurements.

- **Close** button - allows you to close program control of the measurement port. This allows you to change sensor probes and re-initialize the newly-connected sensor.

- **Report** button - opens a report form which allows you to print a Display Calibration Report listing the Manufacturer, Model #, Serial #, reference coordinates, measured coordinates, and comments for the display under test. This is covered in more detail in a following section.

- The **Record** feature allows you to write a single measurement or a series of measurements, with a documenting note, to a file named light.csv (a comma-delimited text file which is easily imported into spreadsheets). This can be used to document a number of single measurements, or to analyze a display's light output response over time.



The Record Measurements dialog allows you to append or overwrite single or continuous readings to a file, with a documenting comment.

- **Measurement Update/Averaging** slider bar - allows you to optimize the measurement update rate and the amount of measurement averaging performed to obtain each updated measurement.
  - Moving the slider bar to the right provides a faster measurement update, with less averaging. When measuring higher light levels, this allows you to obtain faster measurement updates, while still maintaining acceptable measurement stability.
  - Moving the slider bar to the left provides a slower measurement update, with more averaging. When measuring lower light levels, this allows you to obtain greater measurement stability, while still maintaining an acceptable measurement update rate.
- **Dark Calibrate** – allows you to calibrate the balance of the color sensors within the ColorPro III or ColorPro IV. This calibration should be performed when you first start the ColorPro software, then about 15 minutes later when the internal sensor electronics are fully warmed up and stabilized. This precise balancing of the ColorPro sensors provides improved low light accuracy over previous automated balancing techniques.