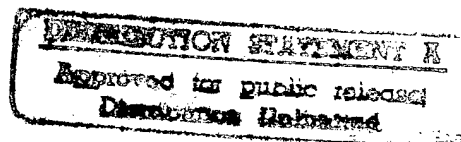


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USING MINOLTA CS100 WITH
MACINTOSH AND NATIONAL NB-DIO-24
TO ACQUIRE DIGITAL-TO-ANALOG
CONVERSION VALUES (DACS)
FOR DESIRED COLOURS.

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Abstract

The Minolta CS100 chromameter was interfaced to a Macintosh Quadra 800 via a National NB-DIO-24 digital input/output board in order to implement unattended acquisition of digital-to-analog conversion values (DACs) corresponding to colours required for psychophysical experimentation. The program was developed and compiled on a Macintosh Quadra 800 with Think C 5.0.

Executive Summary

During the course of psychophysical experimentation using computer driven colour monitors, the experimenter requires the monitor to reproduce certain colours of known characteristics (CIE 1931 x , y , Y_{xy}). To create these colours on the monitor, a set of DAC (digital-to-analog conversion) values for each of the three colour guns must be specified. There are two common methods for obtaining these DACs. If the number of colours required is small, the experimenter can simply measure a test field on the screen with an instrument such as a chromameter, and adjust the DACs by trial and error until suitable DACs are found. If more than just a few colours are required, a predictive calibration method can be used in which the DAC to colour correspondence is modeled using curve fitting routines, and required colours are interpolated. This document reports the implementation of a hybrid method that uses a predictive calibration method to approximate the desired colour followed by a more precise "measure and adjust" method to obtain DACs for requested colours. This procedure is automated and runs unattended.

The program was developed using Think C 5.0 and tested on a Macintosh Quadra 800 hosting a RasterOps 20 inch colour monitor (model 2075RO) and a standard Macintosh 14 inch colour display. The test fields are presented on the 2075RO and measured using Minolta CS100 chromameter. Limitations of the software and hardware set up are discussed.

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FIGURE 2: The start-up screen for the test pattern.

Terminology and Notes

Terminology:

- 8-bit: A value of 0-255 in whole numbers. An 8-bit value can take on $2^8 = 256$ different levels.
- 16-bit: A value of 0-65535 in whole numbers. A 16-bit value can take on $2^{16} = 65536$ different levels.
- Channel: There are three colour channels on a conventional colour monitor: RED GREEN and BLUE. Each channel can be addressed independently.
- CIE 1931: A colour system in which a colour can be specified by a set of chromaticity coordinates (x,y) and luminance (Yxy);
- DAC: Digital-to-analog conversion. This is a digital value (discrete) that is passed from the software to the video hardware. 0 DAC ideally corresponds to 0 voltage applied to a channel.
- gamut: The range of reproduceable colours of a given medium. On a 3-channel colour video monitor, the maximum gamut is determined by the locations of the chromaticities of the three phosphors.

Notes:

- 1) This document and use of the computer program it describes assume that the user has some basic knowledge of how a colour monitor works. Some familiarity with Macintosh operating systems is also assumed. Regarding the workings of a colour monitor, references 1, 4, and 5, plus
Keller, P. (1996). Basics of display color specification.
Information Displays, 1/96, 18-22.
and
Kaufmann, R., & McFadden, S. M. (1989). The use of colour
on electronic displays. DCIEM Report No. 89-TR-42.
are all good resources.
- 2) All filenames in this document are underlined.
- 3) This document was typeset using T_EX.

Introduction

During the course of psychophysical experimentation using computer-driven colour monitors, the experimenter requires the monitor to reproduce certain colours of known characteristics (CIE 1931 x , y , Y_{xy}). For each colour required, a set of DAC (digital-to-analog conversion) values for each of the three colour guns must be specified. Finding the DACs for experimental colours can be time consuming and if the monitor exhibits even relatively small amounts of variability in output, new DACs must be obtained daily or even more frequently to insure reliable reproduction of the desired colours.

There are two common methods for obtaining these DACs. If the number of colours required is small, the experimenter can simply measure a test field on the screen with an instrument such as a chromameter, and adjust the DACs by trial and error until suitable DACs are found. If more than just a few colours are required, a predictive calibration method can be used in which the DAC-to-colour correspondence is modeled using curve fitting routines, and required colours are interpolated. Both these methods have benefits and limitations in their ability to obtain DACs in an efficient and accurate manner(1).

This document reports the implementation of a hybrid method that uses a predictive calibration method to approximate the desired colour followed by a more precise measure-and-adjust method to obtain DACs for requested colours. This procedure is automated and runs without operator supervision. The software/hardware implementation of this hybrid method was performed using a Minolta CS100 chromameter, a Macintosh Quadra 800 computer, a National NB-DIO-24 digital I/O board and a RasterOps 2075RO colour monitor.

General Overview

The executable program is called "cs100-colourseek". Prior to running the program, two text files must be created in the directory where the program will run. A file called "parameter.calib" specifies run-time parameters for the program including screen size (in pixels), sample dot-size (in pixels), background colour, and a few others. This should make the program somewhat portable without recompiling, to other binary-compatible machines with different monitors. A second file called "coords" contains the list of colours for which DACs are being sought. It should contain at least one triplet of numbers specifying the CIE 1931 x,y chromaticity coordinates and the luminance Y_{xy} of a colour that is being sought. These two files should be created with a text editor such as SimpleText or TeachText or any other editor that does not insert control codes. Of course, the program requires 8 bit per gun resolution.

The program runs in two stages. In the first stage, "calibration", it displays a test pattern with a filled dot in the middle of the screen. The colour of the dot is systematically changed and measured to provide data for the fitting routine. This will allow the program to make an informed guess on DAC values that will be a good approximation for the required colours. In the second stage "measure-and-adjust" there is a fine tuning routine that starts at the informed guess DACs then more precisely approaches to the desired colour. The candidate DACs for each desired colour are printed to a file called "all_log".

Specifics: The program is currently implemented on a dual monitor configuration set up. In particular, the current set up is on a Macintosh Quadra 800 computer with a RasterOps Paintboard Li driving a RasterOps 20 inch colour monitor (model 2075RO) and a standard Macintosh 14 inch colour display driven by the internal Quadra 800 video controller. The test colours appear on the 2075RO and a running log of program messages appears on a console window on the Macintosh 14 inch colour display. The executable is called "cs100-colourseek". Prior to execution of this program, two text files must be created in the directory where cs100-colourseek resides.

Required Files

The file parameter.calib must contain six lines that set the following parameters:

xpixels ypixels	(i.e., the real screen size. Likely values are 640 480 or 832 624 or 1024 768.
method	use PLCC or LOGLOG (see below)
dotsize	pixel radius for test dot
r1 g1 b1	background colour DACs 16-bit
start step	start DAC and step size for initial DAC→Lum readings (8-bit values used during calibration stage)
countdown	delay (in seconds) between onset of test dots screen and the start of the reading process

Note that these parameters must all be present and in the specified order. The following is an example of a valid parameter.calib file that contains values used in an actual run of the program. The results from the run using this file are listed in Appendix A.

Example of a valid parameter.calib

```
1024 768
PLCC
35
20480 20480 20480
40 16
15
```

Note: 1) The DACs for the background are 16 bit (0-65535) for historical reasons. The program internally converts them to 8 bit (0-255) by dividing by 256. So for the example (20480 20480 20480), the program will actually send $20480/256 = 80$ to the DAC.

Note: 2) The first time you run the program, you may need time to focus and aim the CS-100. You can set the "countdown" value to 30 seconds or higher to allow time for these functions and to permit time to exit the room so that extraneous light or reflections off clothing do not influence the readings. If any of these control values is weird or missing, the program will log a message to "all_log" and terminate.

Note: 3) Comments are permitted after the values in parameter.calib. For example, the first line could read: 1024 768 width height.

Note: 4) A dotsize of 35 is adequate for the CS100 at 60cm with #135 close-up lens.

IMPORTANT: Because a CRT is being measured, the CS100 should be set to SLOW.

The file coords must contain at least one line containing x, y, and Yxy values separated with at least 1 space. The program will read and process triplets from this file until the end of file is found, or a bogus value is read (see below). There is some error checking:

1) $0.00 \leq x \leq 1.00$, $0.00 \leq y \leq 1.00$, $Y_{xy} \leq Y_{max}$ – where Ymax is the luminance associated with full DAC on all three channels.

2) x,y must fall inside the region defined by the triangle: $(x_r, y_r)(x_g, y_g)(x_b, y_b)$ which represents the maximum gamut of the monitor. Because actual gamut size is a function of luminance, a requested colour that passes the maximum gamut test will not necessarily be reproduceable at all luminances. A colour that fails the maximum gamut test will never be reproduceable. In Figure 1, the gamut of a given monitor is represented by the triangle RGB inside the colour space locus.

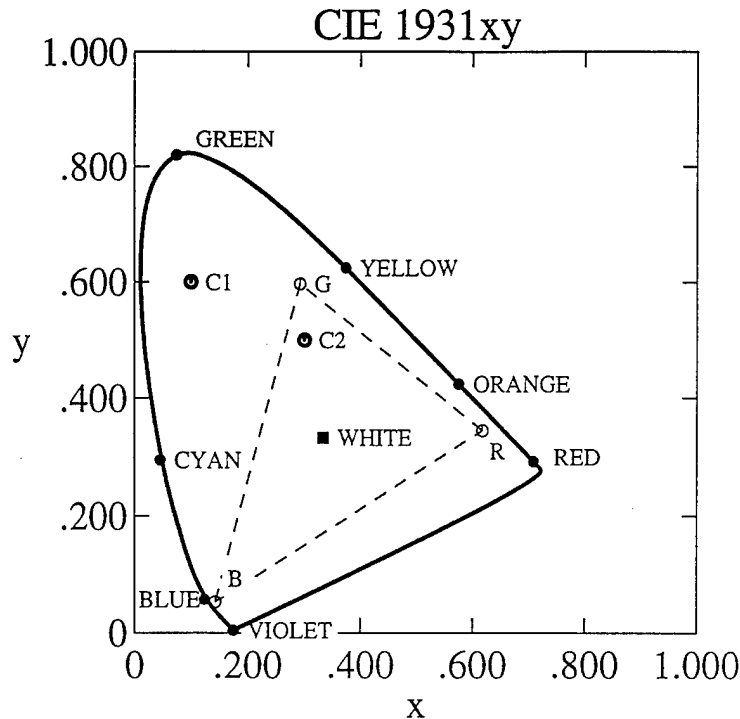


FIGURE 1: CIE 1931 chromaticity diagram with maximum monitor gamut (dotted triangle RGB). Colour C1 cannot be reproduced by the monitor whose channel chromaticities are at points R, G, B. Colour C2 may be reproduceable depending on the luminance required.

The points R, G, and B are the x,y coordinates for Red, Green, and Blue channels of the monitor respectively. These are measured by setting the DAC for a given channel to full (255) and the DAC of 0 to the remaining two channels. Note that colour C1 is never reproduceable on this monitor because it falls outside the gamut whereas colour C2 may be reproduceable at some luminances and not others.

Any colour that fails the gamut test will be ignored. The algorithm that performs this test(2) rejects colours that fall exactly on the gamut boundary and it is quite likely that due to monitor and CS100 variability, these colours (even if achieved at a given reading) may not be reliably obtainable.

The file coords is read **after** the calibration stage because Ymax is measured during the calibration stage. This means that if there are bogus values in the "coords" file, the program will first complete the calibration stage, then seek colours and report candidate DACs up to the point where an offending colour is requested. Upon reading an offending value, the program will log a message to "all_log" and terminate.

Sample contents of coords

```
.330 .330 12.0  
.414 .312 6.0  
.001 .001 20.0
```

Running the program

Double-clicking the “cs100-colourseek” will start the program. Several things should happen immediately. The 2075RO should display a test pattern of five dots that looks something like this:

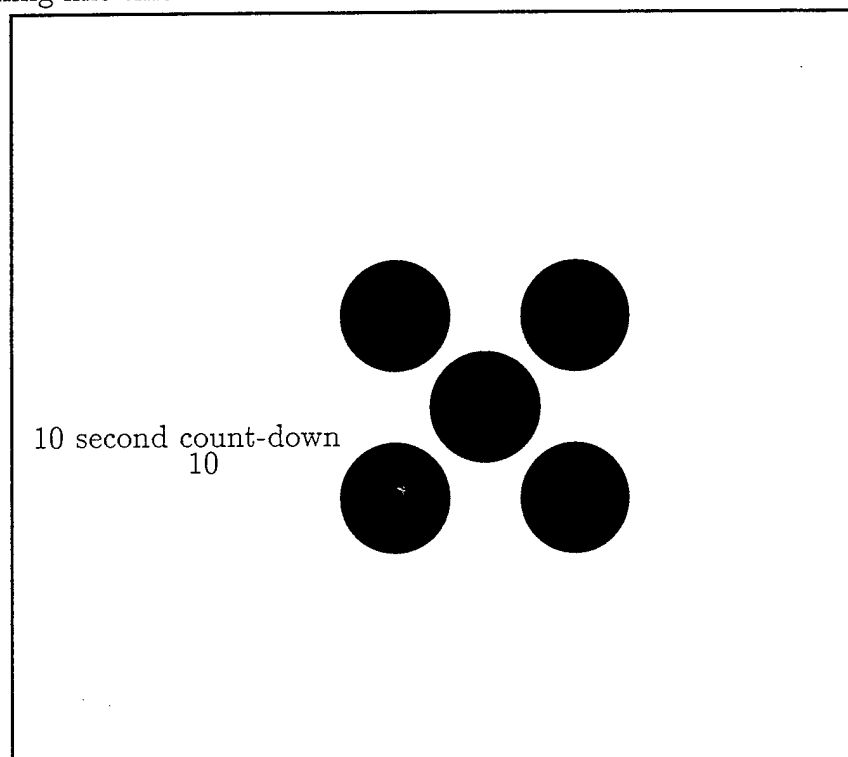


FIGURE 2: The start-up screen for the test pattern.

Also, the second monitor should display a console screen with a running log of the readings and calculations, plus error messages if problems are found with the input files, or reading the CS100.

The CS100 should be aimed and focused on the center dot. The dot size, background colour and count-down time were set in parameter.calib. It is recommended that the dot size and background colour be set as closely as possible to the conditions under which the colours will be used. For example, if you are going to use 1 cm^2 items on a black background in your experiment, then set the background to 0 0 and the dotsize to the number of pixels that give an area of approximately

1 cm^2 . Actually, the ideal is to use a test region identical to that used in your experiment(3); however, currently only a dot test region is implemented. Make sure that the test dot fills the acceptance region on the CS100 (the small open circle in the CS100 viewfinder); else the readings will be inaccurate. If your test dot is too small, affix one of the diopters available from Minolta to allow the CS100 to focus more closely to the screen. (Make sure the test dot is in focus.) Try to match the calibration conditions (room lighting, angle of regard) to the conditions under which the colours will be used.

Following the count-down, the program will begin the calibration stage. In this stage, the dots will be cycled through the DAC range specified in the parameter.calib file. Each channel is independently measured starting at the value 'start' entered in parameter.calib file (40 in the sample above) and incremented by the value 'step' (16 in the sample above). If the combination of start/step does not result in a measurement at full DAC (255) for each channel, a reading at 255 for each channel is forced. With start/step of 40/16 for example, the last regular reading would be 248 ($40+16 \times 13$) so a 255 reading would be forced. After each channel has been read individually, a reading at full DAC for all three channels simultaneously (255 255 255) is taken to get Ymax —the maximum luminance available.

There is a built in check to make sure that the luminance as a function of DAC for each channel is monotonic. If this check fails, the program will terminate. Likely causes for such a failure are:

- 1) The CS100 was bumped so the colour dot does not fully cover the acceptance region of the CS100.
- 2) The monitor has not been sufficiently warmed up and is highly variable. Let the monitor warm up for at least 30 minutes, preferably 60 minutes prior to measuring.
- 3) Someone entered the room and permitted stray light or reflections to influence the readings.
- 4) Fine precision readings (small 'step') in the low DAC region where the monitor and CS100 are unreliable - this might happen if 'start' was set to 10 and 'step' to 2. Test runs with start=40 and step=16 have given good results.
- 4) Take the lens cap off!

It takes about 5 seconds per reading so 12 steps per gun would require about 3 minutes reading time. More readings will likely give better prediction, but there is likely a diminishing return for additional readings after about 16(4).

Once the readings have been taken, the program does some internal calculations to prepare it to approximate the colours that will be requested in the file coords.

There are two preliminary calibration algorithms coded. The first is the LOG-LOG method described, but not recommended(4) which was implemented to test the claim(4) that this method is not as accurate as PLCC (see below). A few test runs with the LOG-LOG method showed it to be quite poor at entering colour space near the required colour, so unless there is a really good reason to use LOG-LOG, do not.

The second is the PLCC (piecewise linear assuming constant channel chromaticity)-see below. It gives quite good results because a ceiling and floor for a given interpolation are naturally imposed by interpolating between two real data points as opposed to predicting based on linear regression which imposes no such local limits.

In either case, the values arrived at are a start for the "measure- and-adjust" method (see ref. 1). This program assumes constant channel chromaticity(1,5). The more constant channel chromaticity is violated, the poorer the initial guess. Violation is most prominent at lower DAC values and is a function of both monitor and CS100 variability at low DAC/luminance settings.

During the "measure-and-adjust", candidate DACs for the required colours are reported. For each requested colour in the file coords, up to 6 candidates are reported, but these may not necessarily be unique. That is, one set of DACs for a requested colour may be repeated several times because of the way the algorithm bounces around once it gets close to a required colour. Currently the tolerances (how far can a measurement be off to still qualify) are $|\Delta| < .1$ on Luminance Y_{xy} and $|\Delta| < .004$ on x and y .

Procedure

Locate the program cs100-colourseek. Create parameter.calib and coords in the same directory as cs100-colourseek with a text editor. Remember that the file all_log will be overwritten so rename it if you wish to retain its contents. Verify the hardware setup: make sure the CS100 is plugged in, has a good battery, and is switched on ("Yxy" should be on the CS100 external LCD). It is also recommended that no other programs be running in background during execution of cs100-colourseek. Look under the "Finder" and make sure no screen blankers, network programs, or other utilities are active. Double click cs100-colourseek, verify that the CS100 is on target and leave the room. If all files are present and valid, a few minutes later, the colours should be available in the all_log file. Upon completion of the "measure-and-adjust" stage of the program, the console on the 14 inch monitor will wait for a <return> to exit the program. Pressing <return> should reinstate the desktop and normal

control of the mouse.

Appendix 'A' contains a copy of the all_log file that was generated using the parameters specified in parameter.calib and coords above.

Discussion

Results of informal testing of this program have shown:

- 1) For requested colours with $Y_{xy} > 10$, the algorithm can easily find several candidate DAC sets within 50 tries. It zeroes in on a very near set of DACs quickly and bounces back and forth around it. Because of the way the measure-and-adjust algorithm is implemented, it will find a good set of DACs, but perhaps not the best.
- 2) There is the potential for the program to fail to find colours close to the edge of the gamut due to monitor and CS100 variance.
- 3) Sometimes the CS100 will fail to return values and the read-from-cs100 routine times out. The console will report the error and keep trying.

There are a few things to consider about the DACs obtained for colours by this program. First, the CS100 and the monitor are very likely to exhibit significant variability over time. This means that the colours obtained from a given set of DACs may not be useable the next day. Because this program is quick and easy to use, (a new set of 10 DACs can be obtained in under 10 minutes) it is worth acquiring new DACs each day if colour control is an important aspect to an experiment. Second, some monitors exhibit spatial variability (the same DACs on two parts of the screen give different chromaticities). If you are going to use the colours systematically at other locations (e.g. a target always in the upper left of the screen, then point the CS100 at the most appropriate non-central test dot (see, Figure 2). It may also be possible to use the xpixel ypixel setting in parameter.calib to get the test dots to fall where your experimental stimuli will be placed. Third, a colour patch surrounded by a differently coloured field may undergo 'chromatic induction' which means that the colour of the patch will be influenced by the surround. For example, a white patch surrounded by a green field may appear slightly red. The point is that the CS100 will not take this into consideration, but you may have to. On a more practical level, make certain that the contrast and brightness controls are either locked or set to a known position (at detent or full) because any movement on these controls will affect the colours reproduced. Experimental subjects have been known to adjust dials during experiments!

Acknowledgment

Parts of this code are lifted by permission from "test minolta.c" in project "test minolta. π " that read Y,x,y from CS100 through NB-DIO-24 card. It was originally written and donated by:

Rob McPeck
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of the Cavanagh Lab. The original read and reported to stdout (console), the Y,x,y of whatever the CS100 was pointed at.

Thanks to Sharon McFadden for her input at various stages of this project.

References

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- 5 Jimenez del Barco, L, Diaz, J. A., Jimenez, J. R., & Rubino, M. (1995). Considerations on the calibration of color displays assuming constant channel chromaticity. *Color Research and Application*, 20, 377-387.

Appendix A: a copy of all_log from a test run of cs100-colourseek.

opened parameter file

starting calibration stage

will force reading at full dac for each channel

opened log output file

Mon Jul 8 11:44:04 1996

11:44:19 R= 40 G= 0 B= 0: Y= 0.278000 x= 0.432000 y= 0.368700
11:44:23 R= 56 G= 0 B= 0: Y= 0.418000 x= 0.504900 y= 0.348900
11:44:27 R= 72 G= 0 B= 0: Y= 0.675000 x= 0.565800 y= 0.355300
11:44:31 R= 88 G= 0 B= 0: Y= 1.045000 x= 0.582000 y= 0.350900
11:44:34 R= 104 G= 0 B= 0: Y= 1.538000 x= 0.594200 y= 0.349100
11:44:38 R= 120 G= 0 B= 0: Y= 2.160000 x= 0.603300 y= 0.344800
11:44:42 R= 136 G= 0 B= 0: Y= 2.923000 x= 0.611200 y= 0.349900
11:44:46 R= 152 G= 0 B= 0: Y= 3.833000 x= 0.612200 y= 0.349100
11:44:50 R= 168 G= 0 B= 0: Y= 4.900000 x= 0.614900 y= 0.347800
11:44:54 R= 184 G= 0 B= 0: Y= 6.110000 x= 0.617400 y= 0.348500
11:44:57 R= 200 G= 0 B= 0: Y= 7.495000 x= 0.616900 y= 0.348300
11:45:01 R= 216 G= 0 B= 0: Y= 9.057000 x= 0.618200 y= 0.347300
11:45:05 R= 232 G= 0 B= 0: Y= 10.790000 x= 0.618700 y= 0.348200
11:45:09 R= 248 G= 0 B= 0: Y= 12.710000 x= 0.619400 y= 0.347800
11:45:13 R= 255 G= 0 B= 0: Y= 13.580000 x= 0.620300 y= 0.348300
11:45:16 R= 0 G= 40 B= 0: Y= 0.575000 x= 0.322000 y= 0.472600
11:45:20 R= 0 G= 56 B= 0: Y= 1.153000 x= 0.322800 y= 0.528200
11:45:24 R= 0 G= 72 B= 0: Y= 2.060000 x= 0.309500 y= 0.566700
11:45:28 R= 0 G= 88 B= 0: Y= 3.338000 x= 0.299200 y= 0.583000
11:45:32 R= 0 G= 104 B= 0: Y= 4.995000 x= 0.299800 y= 0.583400
11:45:35 R= 0 G= 120 B= 0: Y= 7.055000 x= 0.299200 y= 0.591800
11:45:39 R= 0 G= 136 B= 0: Y= 9.568000 x= 0.297200 y= 0.592800
11:45:43 R= 0 G= 152 B= 0: Y= 12.540000 x= 0.297000 y= 0.592100
11:45:47 R= 0 G= 168 B= 0: Y= 15.980000 x= 0.296900 y= 0.593500
11:45:51 R= 0 G= 184 B= 0: Y= 19.900000 x= 0.296500 y= 0.595800
11:45:55 R= 0 G= 200 B= 0: Y= 24.300000 x= 0.295800 y= 0.595800
11:45:58 R= 0 G= 216 B= 0: Y= 29.210000 x= 0.295200 y= 0.596200
11:46:02 R= 0 G= 232 B= 0: Y= 34.620000 x= 0.294500 y= 0.597200
11:46:06 R= 0 G= 248 B= 0: Y= 40.560000 x= 0.294200 y= 0.596900
11:46:10 R= 0 G= 255 B= 0: Y= 43.240000 x= 0.294200 y= 0.596500
11:46:14 R= 0 G= 0 B= 40: Y= 0.198000 x= 0.244500 y= 0.199600
11:46:18 R= 0 G= 0 B= 56: Y= 0.255000 x= 0.209600 y= 0.125600
11:46:21 R= 0 G= 0 B= 72: Y= 0.347000 x= 0.176400 y= 0.094700
11:46:25 R= 0 G= 0 B= 88: Y= 0.475000 x= 0.156600 y= 0.077400
11:46:29 R= 0 G= 0 B= 104: Y= 0.663000 x= 0.155700 y= 0.069200
11:46:33 R= 0 G= 0 B= 120: Y= 0.888000 x= 0.151100 y= 0.064300
11:46:37 R= 0 G= 0 B= 136: Y= 1.168000 x= 0.149100 y= 0.061600
11:46:40 R= 0 G= 0 B= 152: Y= 1.508000 x= 0.149100 y= 0.059600
11:46:44 R= 0 G= 0 B= 168: Y= 1.900000 x= 0.146700 y= 0.058500
11:46:48 R= 0 G= 0 B= 184: Y= 2.345000 x= 0.145500 y= 0.057600
11:46:52 R= 0 G= 0 B= 200: Y= 2.855000 x= 0.145800 y= 0.056900
11:46:56 R= 0 G= 0 B= 216: Y= 3.405000 x= 0.144700 y= 0.056300
11:46:59 R= 0 G= 0 B= 232: Y= 4.025000 x= 0.144200 y= 0.056000
11:47:03 R= 0 G= 0 B= 248: Y= 4.698000 x= 0.144400 y= 0.055600

```

11:47:07 R= 0 G= 0 B= 255: Y= 5.005000 x= 0.144600 y= 0.055500
15 readings taken per gun.
Now read R=G=B=255
11:47:11 R= 255 G= 255 B= 255: Y= 61.700000 x= 0.290300 y= 0.307400
checking for monotonicity
Using PLCC
Tristimulus Values
X= 24.1851 Y= 13.5800 Z= 1.2243 i=0 n=14
X= 21.3264 Y= 43.2400 Z= 7.9231 i=1 n=14
X= 13.0401 Y= 5.0050 Z= 72.1351 i=2 n=14
linearity departures: X= 0.2838 Y= 0.1250 Z= 0.5346
determinant 16387
opening coords file
requested:
x=0.330 y=0.330 Yxy=12.000000 X=12.000000 Y=12.000000 Z=12.363635
requested colour inside gamut.. proceeding
red lum = 3.513232 starting at: red DAC = 146.377701
green lum = 7.749432 starting at: green DAC = 124.421371
blue lum = 0.737336 starting at: blue DAC = 109.286118
entering measure_and_adjust
starting:
R=147 G=125 B=110 aim:Y= 12.00 x= 0.3300 y= 0.3300
R=147 G=125 B=119: Y= 11.92 x= 0.3299 y= 0.3304
R=148 G=125 B=119: Y= 11.99 x= 0.3314 y= 0.3303
R=148 G=125 B=120: Y= 12.00 x= 0.3300 y= 0.3281
R=148 G=125 B=119: Y= 11.97 x= 0.3311 y= 0.3303
R=148 G=125 B=120: Y= 12.00 x= 0.3301 y= 0.3284
R=147 G=125 B=120: Y= 11.94 x= 0.3283 y= 0.3285
R=148 G=125 B=120: Y= 11.99 x= 0.3299 y= 0.3288
requested:
x=0.414 y=0.312 Yxy=6.000000 X=7.961538 Y=6.000000 Z=5.269230
requested colour inside gamut.. proceeding
red lum = 3.367782 starting at: red DAC = 143.820343
green lum = 2.317144 starting at: green DAC = 75.219330
blue lum = 0.315074 starting at: blue DAC = 66.447586
entering measure_and_adjust
starting:
R=144 G=76 B=67 aim:Y= 6.00 x= 0.4140 y= 0.3120
R=145 G= 76 B= 87: Y= 5.94 x= 0.4146 y= 0.3108
R=145 G= 77 B= 87: Y= 6.01 x= 0.4142 y= 0.3121
R=144 G= 77 B= 87: Y= 5.96 x= 0.4127 y= 0.3123
R=145 G= 77 B= 87: Y= 6.02 x= 0.4137 y= 0.3132
R=145 G= 76 B= 87: Y= 5.95 x= 0.4149 y= 0.3101
R=145 G= 77 B= 87: Y= 6.01 x= 0.4146 y= 0.3126
R=144 G= 77 B= 87: Y= 5.96 x= 0.4127 y= 0.3122
requested:
x=0.001 y=0.001 Yxy=20.000000 X=20.000000 Y=20.000000 Z=19960.000000
+++++++outside gamut, skipping this one.+++++++

```

Some notes about this copy of all_log:

The lines following the date are from the calibration stage where the channels are cycled independently. The most important lines for the user are those right after the two lines:

starting
entering measure_and_adjust

These lines report the requested colour, and up to 7 candidate DACs and their corresponding chromaticities. Note that the final colour requested fell outside the maximum gamut and was skipped. For the first colour requested, ($x=.330$, $y=.330$, $Y_{xy}=12.0$), the second, third, and fourth set of DACs look the best, so if you wanted to use this colour in an experiment and you decided that the fourth set suits your purposes, use DACs (R,G,B) = (148,125,119). Note that sets three, five, and seven have the same DACs but slightly different chromaticity coordinates. This is due to variability in the CS100 and the monitor.

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The Minolta CS100 chromameter was interfaced to a Macintosh Quadra 800 via a National NB-DIO-24 digital input/output board in order to implement unattended acquisition of digital-to-analog conversion values (DACs) corresponding to colours required for psychophysical experimentation. The program was developed and compiled on a MacIntosh Quadra 800 with Think C 5.0.

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