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(54) METHOD OF OPTIMIZING VIDEO OUTPUT FOR A COMPUTER SYSTEM WITH DIGITAL-TO-ANALOG CONVERTER CHARACTERIZATION DATA

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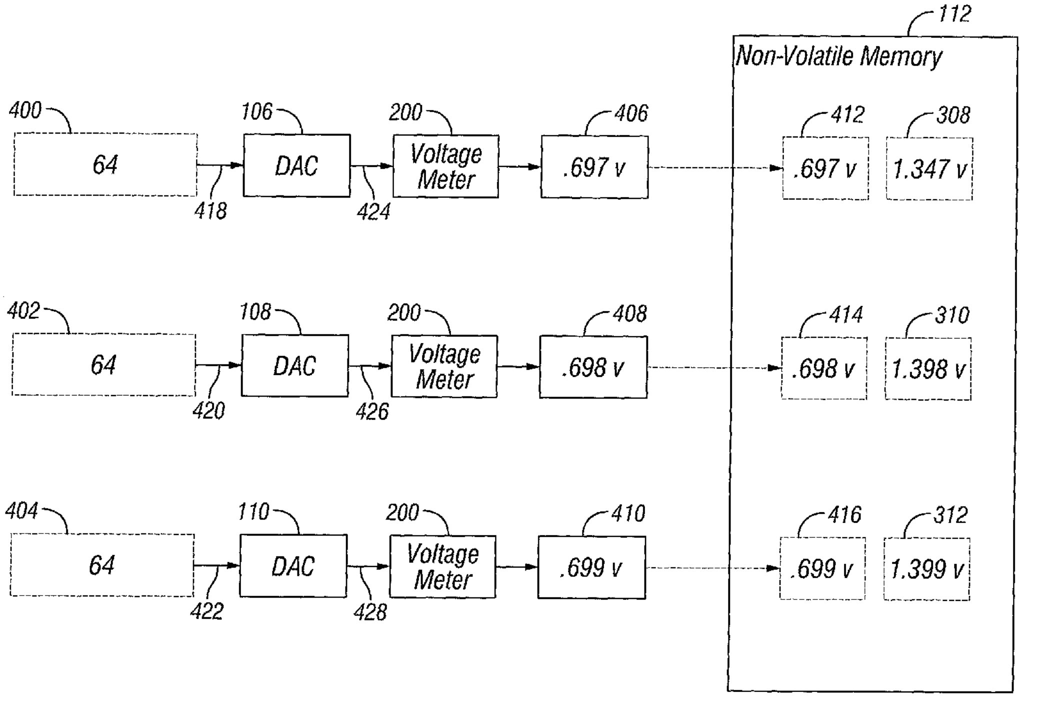
(57) **ABSTRACT**

A computer system provides a technique of optimizing video output utilizing digital-to-analog converter characterization data. A plurality of digital-to-analog converters for a plurality of color channels of a video subsystem of the computer system are driven with a set of predetermined input digital values. The resulting plurality of output analog voltages from the plurality of digital-to-analog converters are measured and then stored in a non-volatile memory as a plurality of digital characterization values. Color management software of the computer system performs color correction based on the plurality of digital characterization values.



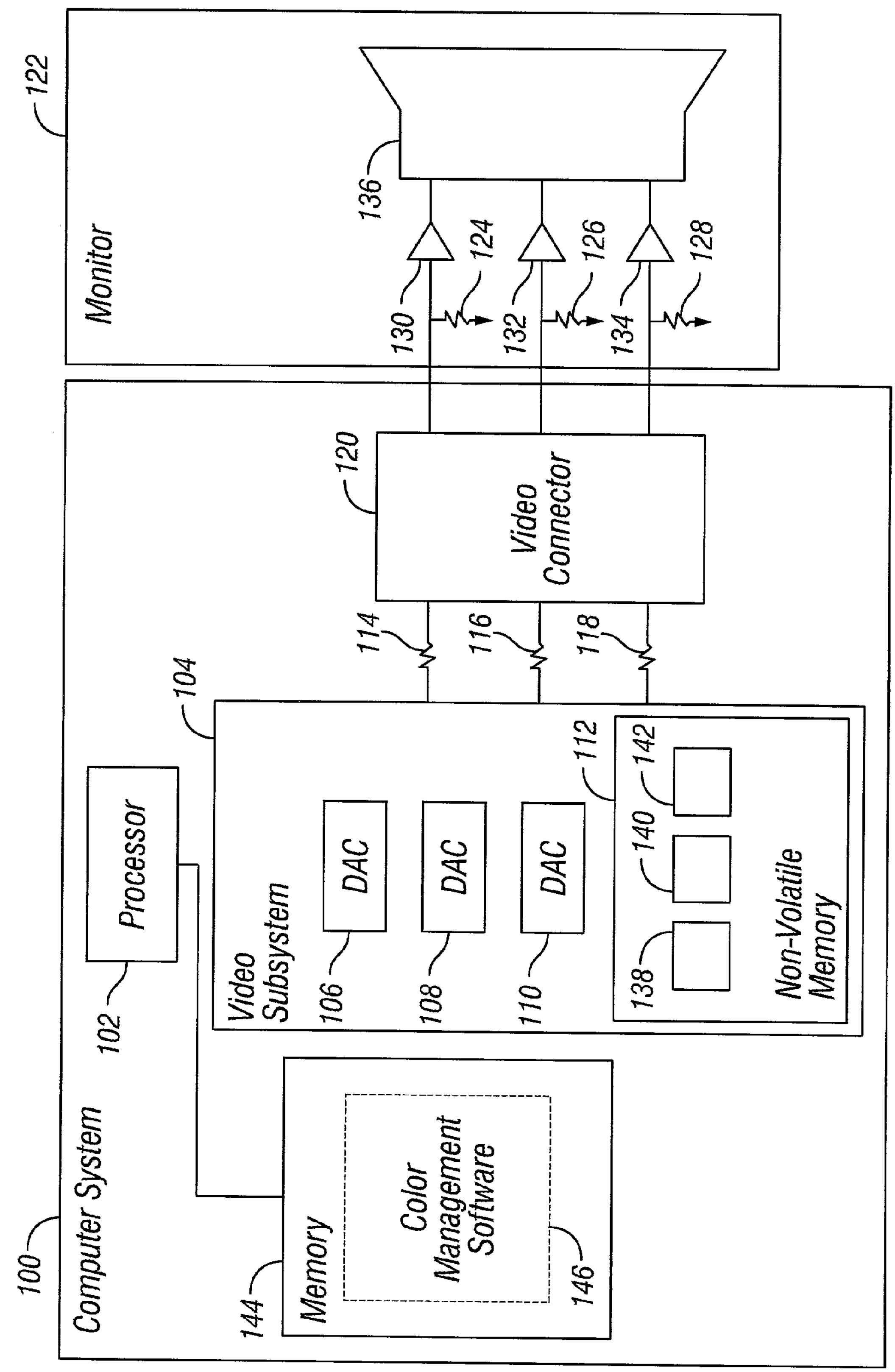

Monitor
122
136
124
126
128
130
132
134
Video Connector
120
114
116
118
104
Video Subsystem
DAC
DAC
DAC
106
108
110
112
Non-Volatile Memory
138
140
142
Processor
102
Computer System
100
Memory
144
Color Management Software
146

FIG. 1

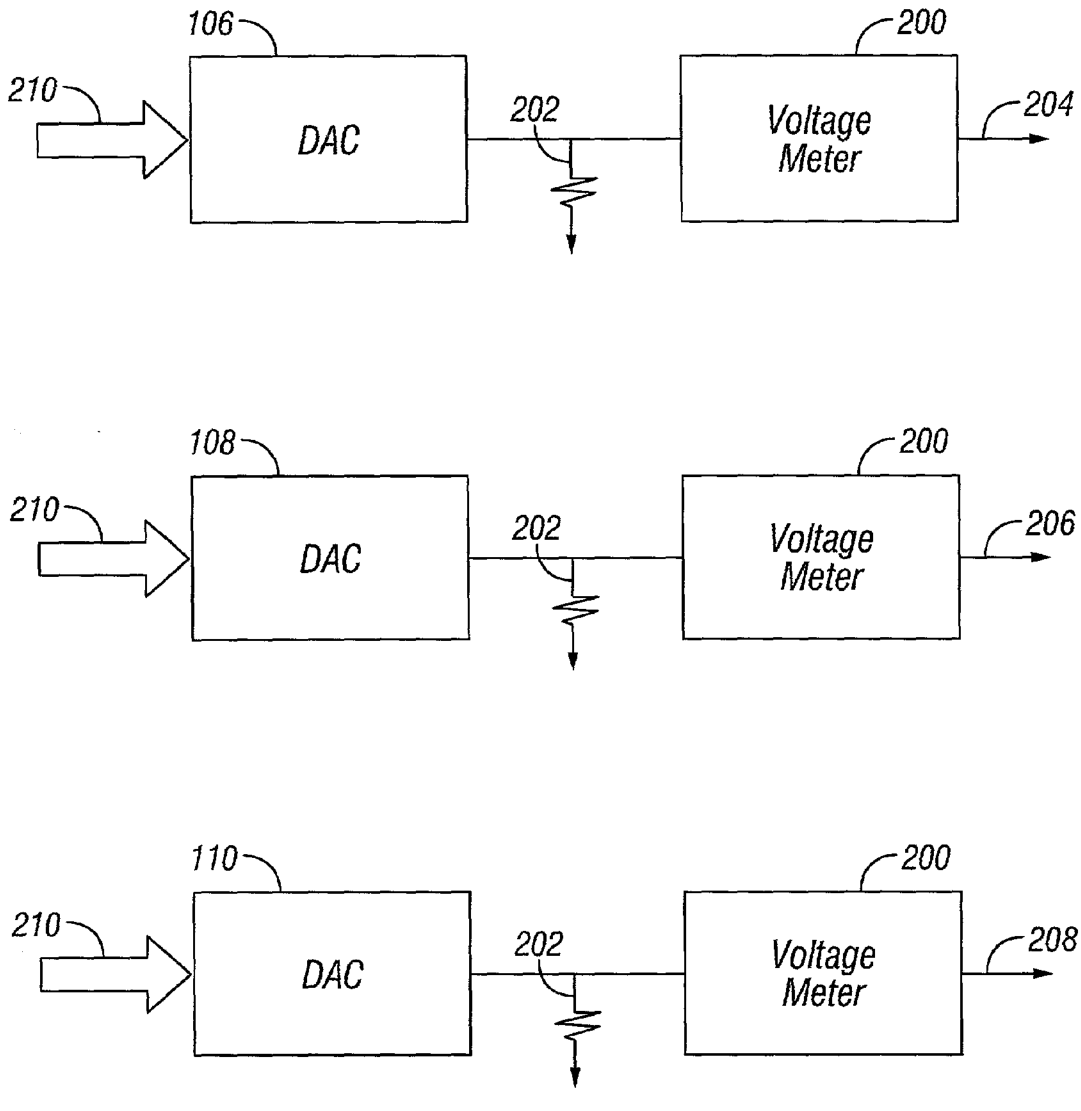

106
210
DAC
202
200
Voltage Meter
204
108
210
DAC
202
200
Voltage Meter
206
110
210
DAC
202
200
Voltage Meter
208

FIG. 2

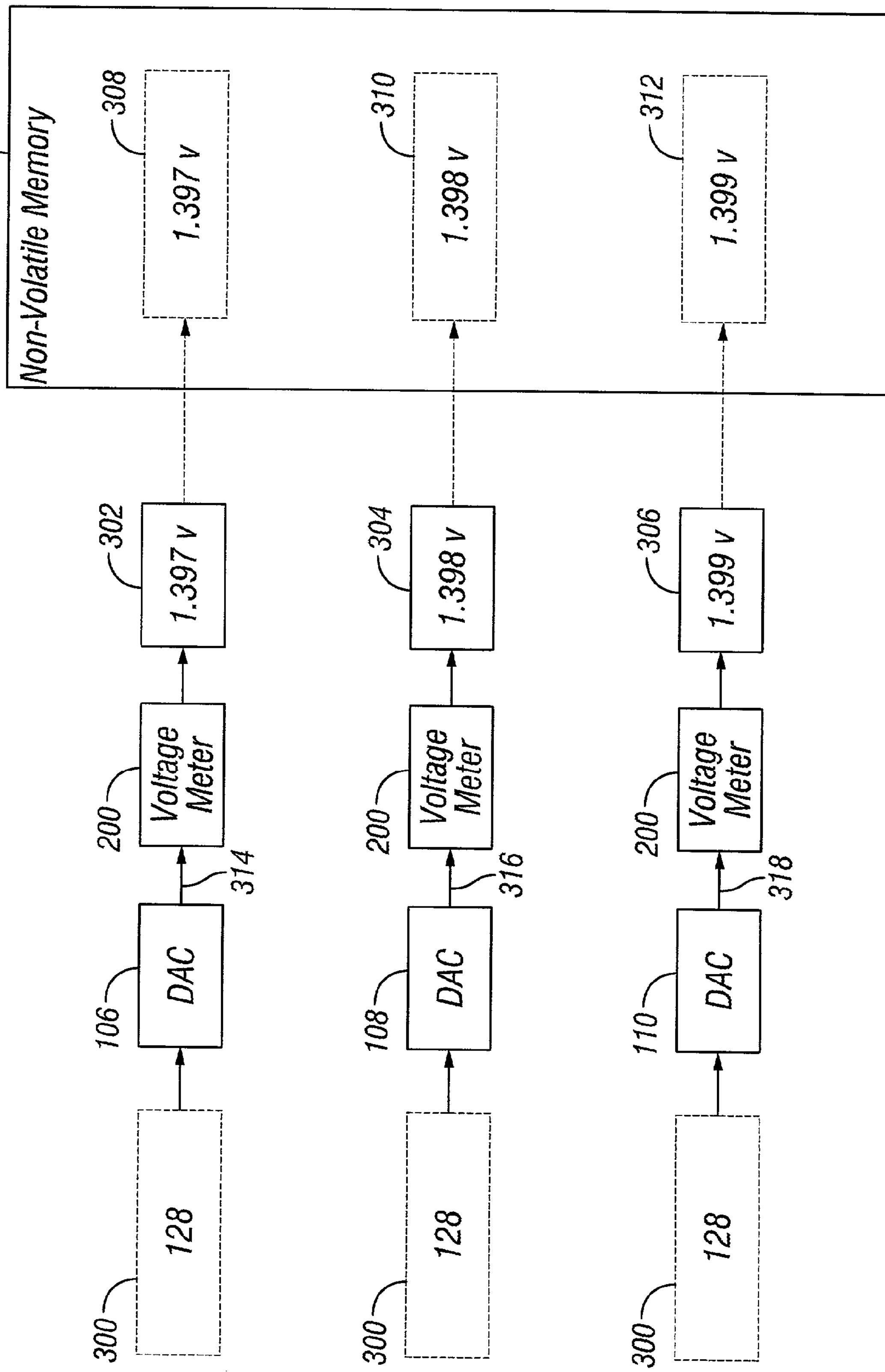

112
Non-Volatile Memory
308
1.397 v
310
1.398 v
312
1.399 v
302
1.397 v
304
1.398 v
306
1.399 v
200
Voltage Meter
314
316
318
106
108
110
DAC
300
128

FIG. 3

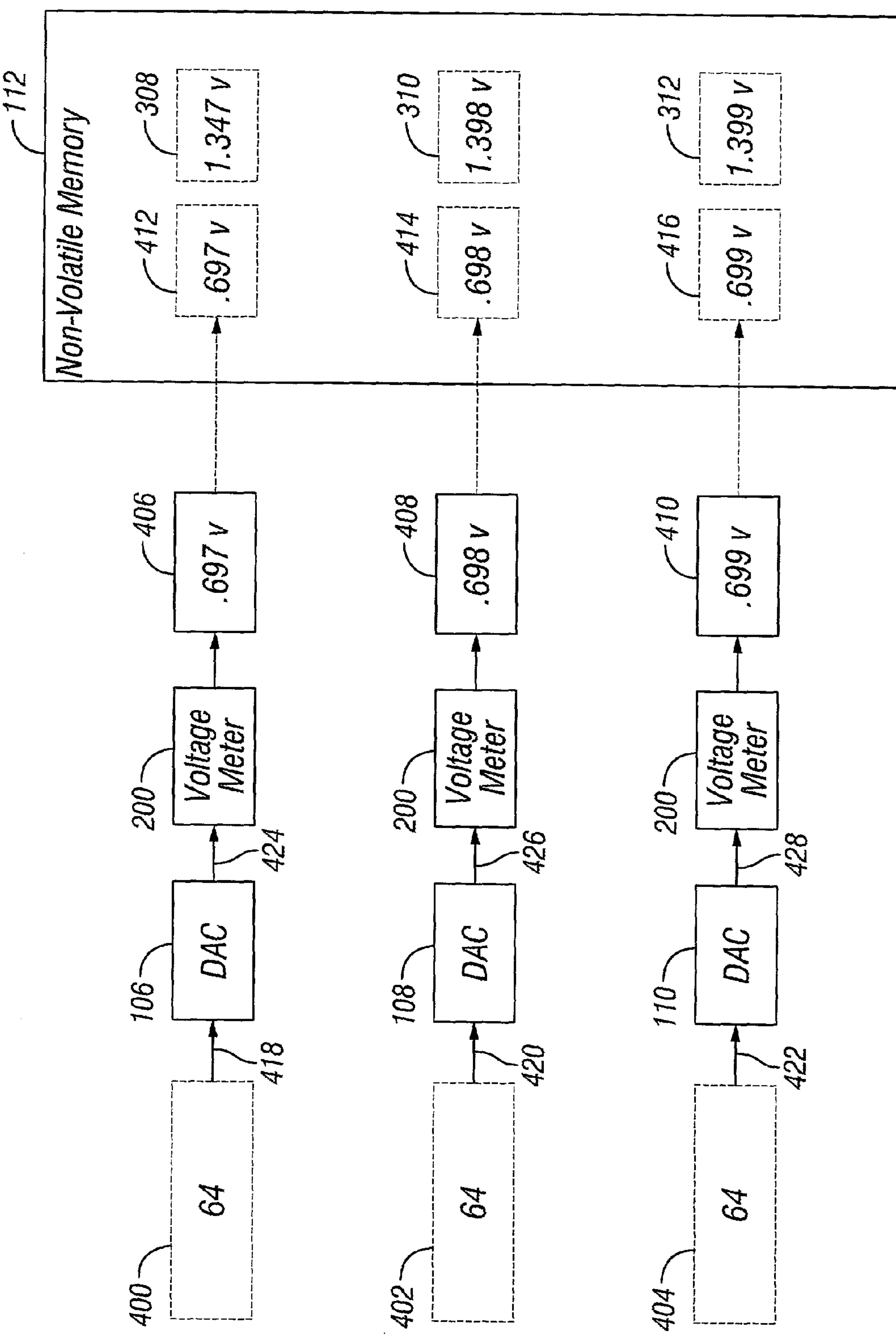

112
Non-Volatile Memory
308
1.347 v
310
1.398 v
312
1.399 v
412
.697 v
414
.698 v
416
.699 v
406
.697 v
408
.698 v
410
.699 v
200
Voltage Meter
200
Voltage Meter
200
Voltage Meter
424
426
428
106
DAC
108
DAC
110
DAC
418
420
422
400
64
402
64
404
64

FIG. 4

METHOD OF OPTIMIZING VIDEO OUTPUT FOR A COMPUTER SYSTEM WITH DIGITAL-TO-ANALOG CONVERTER CHARACTERIZATION DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable.

STATEMENTS REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable.

REFERENCE TO A MICROFICHE APPENDIX

[0003] Not Applicable.

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention

[0005] The present invention generally relates to video optimization for a computer system and more particularly to a method of optimizing video output for a computer system with digital-to-analog converter characterization data.

[0006] 2. Description of the Related Art

[0007] A video subsystem of a computer system traditionally provides a digital-to-analog converter (DAC) for each primary color channel for interfacing to a monitor. Each DAC typically includes a voltage source that generates an analog voltage as a function of a reference voltage and an input digital value. The reference voltage is usually defined with respect to a set of resistors. When the computer is connected to the monitor, these resistors in the video subsystem typically form a resistor divider arrangement with a set of resistors in the monitor. Each resistor is typically 75 ohms. Where each resistor value is equal, the resistor divider is a one-half resistor divider. Based on the one-half resistor divider and the typical voltage range of 0-0.7 volts in the monitor, the voltage range for the voltage source of each DAC is 0-1.4 volts. Even though each DAC resides on the same chip and uses the voltage source as a common reference, each DAC does not produce the same output voltage in response to a same digital input value. As such, there is a certain percentage of variability among the DACs. Similarly, there is variability among the resistors coupled to the DACs within a certain resistor tolerance. Both forms of variability inject imprecision into the color channels of the video subsystem. This imprecision has constrained color management of the computer system.

BRIEF SUMMARY OF THE INVENTION

[0008] Briefly, a computer system provides a technique of optimizing video output utilizing digital-to-analog converter characterization data. A plurality of digital-to-analog converters for a plurality of color channels of a video subsystem of the computer system are driven with a set of predetermined input digital values. The resulting plurality of output analog voltages from the plurality of digital-to-analog converters are measured and then stored in a non-volatile memory as a plurality of digital characterization values. Color management software of the computer system performs color correction based on the plurality of digital characterization values.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0009] A better understanding of the present invention can be obtained when the following detailed description of the invention is considered in conjunction with the following drawings in which:

[0010] **FIG. 1** is a schematic diagram of an exemplary monitor connected to a computer system with DAC characterization data;

[0011] **FIG. 2** is a diagram of an exemplary technique of acquiring DAC characterization data for storage in the computer system of **FIG. 1**;

[0012] **FIG. 3** is a data flow diagram of an exemplary technique of measuring and storing characterization data for the DACs of **FIG. 1**; and

[0013] **FIG. 4** is a data flow diagram of an exemplary technique of measuring and storing additional characterization data for the DACs of **FIG. 1**.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Referring to **FIG. 1**, an exemplary computer system **100** with DAC characterization data in relation to a cathode ray tube (CRT) monitor **122** is shown. The computer system **100** includes a processor **102** coupled to a video or graphics subsystem **104**. If the computer system **100** is a high-performance system, then the video subsystem **104** may be contained in a graphics plug-in card. If the computer system **100** is a low cost system, then the video subsystem **100** may be contained in a graphics controller chip on the motherboard of the computer system **100**. The video subsystem **100** includes digital-to-analog converters (DACs) **106-110** such that each primary color channel corresponds to a particular digital-to-analog converter. The DACs **106-110** may be part of a DAC interface of a graphics controller chip or card. For explanatory purposes, DAC **106** will be treated as corresponding to the "R" or red color channel; DAC **108** will be treated as corresponding to the "G" or green color channel; and DAC **110** will be treated as corresponding to the "B" or blue color channel. Each DAC **106-110** is coupled respectively to a resistor **114-118**. The resistors **114-118** are coupled to a video connector **120** which directly connects to the monitor **122**. The video connector **120** is typically a DB15 VGA (video graphics adapter) connector. Three pins of the connector **120** are used for the primary color channels, and another three pins of the connector **120** are used as ground signals for the primary color channels. The video subsystem **104** further includes a non-volatile memory **112** storing DAC characterization data **138-142** for the primary color channels discussed below in connection with FIGS. **3-4**. The non-volatile memory **112**, for example, may be an electrically erasable programmable read-only memory (EEPROM). Certain typical components of a computer system are omitted from **FIG. 1** for sake of clarity.

[0015] The computer system **100** further includes a memory **144** storing color management software **146** which reads the non-volatile memory **112** and performs color correction or optimization for the computer system **100** based on the DAC characterization data **138-142** in a manner that compensates for DAC variability. Color correction generally refers to rendering consistent or perceptually uniform color for images. Such color correction may involve matrix operations, filtering and/or look-up tables to map colors of the primary color channels to a standard or known color space such as sRGB. The DAC characterization data **138-142** may be included by the color management software **146** in a color profile for the video subsystem **104**. The color management software **146** may be part of an operating system or alternatively may be a distinct application. In interpreting the DAC characterization data **138-142**, the color management software **146** may assume linearity between the measured DAC data **138-142**. In an alternative embodiment, the color management software **146** may employ a suitable non-linear mathematical model based on the measured DAC data **138-142**. The measurement of the DAC characterization data **138-142** is discussed below in connection with FIGS. 2-4. Since characterization data **138-142** is stored for each DAC **106-110**, the color management software **146** independently color corrects for each DAC **106-110**.

[**0016**] The monitor **122** includes a resistor-buffer combination or termination for each primary color channel. For explanatory purposes, resistor **124** and buffer **130** will be treated as corresponding to the "R" or red color channel; resistor **126** and buffer **132** will be treated as corresponding to the "G" or green color channel; and resistor **128** and buffer **134** will be treated as corresponding to the "B" or blue color channel. Buffers **130-134** are coupled to a picture tube **136**. The brightness of each primary color displayed on the picture tube **136** is a function of the input voltage to the monitor **122** corresponding to the primary color. A cathode ray tube (CRT) is one example of a picture tube **136**. Alternatively, the monitor **122** may be a flat panel display.

[**0017**] Referring to **FIG. 2**, an exemplary technique of acquiring DAC characterization data for storage in the computer system **100** is shown. Each DAC **106-110** is driven with a predetermined digital input value or number **210**. As an example, the value may be the maximum digital input value for each DAC **106-110**. If each DAC is an 8-bit DAC, the maximum digital input value will correspond to "128" as shown in **FIG. 3**. The output analog voltage of each DAC **106-110** is measured with a voltage meter **200** or other digital equipment capable of measuring voltage, such as an oscilloscope, coupled to a high precision 75 ohm termination load resistor **202**. A high precision resistor is generally understood to be a resistor with a highly acceptable or extremely small resistor tolerance in this particular context. Those skilled in the art will appreciate the technique for calculating an appropriate value for the precision resistor **202**. The voltage meter output signals **204-206** respectively represent the output analog voltages of the DACS **106-110**. The voltage meter **200** may be part of a video subsystem characterization station. Other configurations than that shown in **FIG. 2** may be utilized to accomplish precision voltage measurements of the DACs **106-110**. The DAC measurements may be taken on the production line in the factory of the manufacturer of the video subsystem **104**, such as during the manufacturing test process, before the video subsystem **104** is supplied to the computer system manufacturer. In this way, the DAC characterization values may be pre-stored in the non-volatile memory **112** of the video subsystem **104**. Alternatively, the DAC measurement could be taken in the factory of the manufacturer of the DACs **106-110**. An advantage of these approaches is a lack of user intervention in characterizing the DACs **106-110**.

[**0018**] Generally, at least two measurements per DAC **106-110** should be taken to characterize each DAC **106-110**. For example, the voltage responses of each DAC **106-110** can be measured based on a minimum digital input value and a maximum digital input value. While it is widely know that DACs are not totally linear, it may be assumed that the DACs **106-110** behave linearly between two output analog voltages measured in response to the two digital input values. In that circumstance, the pair of measured output analog voltages for each DAC **106-110** represents the transfer function of the associated DAC. More particularly, if linear behavior is assumed for each DAC **106-110**, the slope as defined based on the measured output analog voltages represents the transfer function of the associated DAC. If it assumed that each DAC **106-110** would result in a zero output analog voltage in response to a digital input value of zero, then a single measurement for each DAC **106-110** can be taken, rather than two measurements.

[**0019**] Referring to **FIG. 3**, an exemplary data flow for measuring and storing DAC characterization data for the DACs **106-110** is shown. The digital input value **300** for "128" is input into each DAC **106-110**. If the DACs **106-110** are 8-bit DACs, then the DACs **106-110** are being driven with the maximum digital input value for the DACs **106-110**. The analog signals **314-318** indicate the output analog voltages from the DACs **106-110** in response to the digital input value **300**. A voltage meter **200** or other digital equipment capable of measuring voltage directly or indirectly is used to measure the analog signals **314-318**. It should be understood that voltage meter readings may be taken at the same or different times for the DACs **106-110** and that multiple voltage meters may be used for the measurements as opposed to a single voltage meter. It should also be understood that diagnostic software may be used in conjunction with voltage meter **200** to record the measurements. A digital output signal **302** from the voltage meter **200** indicates a voltage of 1.397 volts for the DAC **106**; a digital output signal **304** from the voltage meter **200** indicates a voltage of 1.398 volts for the DAC **108**; and a digital output signal **306** from the voltage meter **200** indicates a voltage of 1.399 volts for the DAC **110**. Since a voltage meter reading includes blanking intervals, the reading should be converted through calculations to the digital voltage output signals **302-306**. Thus, if a voltage meter is used for the measurements, the appropriate processing should be utilized to achieve the voltage output level of each DAC **106-110**. The digital data **308-312** of the output signals **302-306** is stored or recorded in the non-volatile memory **112**. This information serves as characterization data for analog performance of the DACs **106-110**. For example, such information indicates the variability among the DACs **106-110** in response to the same digital input value. More generally, this technique serves to characterize the color channels of the video subsystem **104** or graphics controller.

[**0020**] Referring to **FIG. 4**, an additional measurement for the DACs **106-110** is taken and stored. In this example, the digital input value **400** for "64" is input into each DAC **106-110**. The analog signals **418-422** indicate the output analog voltages from the DACs **106-110** in response to the digital input value **400**. Similar to **FIG. 3**, the voltage meter **200** is used to measure the analog signals **424-428**. A digital output signal **406** from the voltage meter **200** indicates a voltage of 0.697 volts for the DAC **106**; a digital output signal **408** from the voltage meter **200** indicates a voltage of

0.698 volts for the DAC **108**; and a digital output signal **410** indicates a voltage of 0.699 volts for the DAC **110**. The digital output signals **406-410** thus indicate a channel-to-channel mismatch of 0.001 volts between DAC **106** and DAC **108**, a channel-to-channel mismatch of 0.001 volts between DAC **108** and DAC **110**, and a channel-to-channel mismatch of 0.002 volts between DAC **106** and DAC **110**. The digital data of the output signals **406-410** is stored in the non-volatile memory **112**. The non-voltage memory **112** thereby stores data for two sets of voltage measurements for each DAC **106-110**. Any number of voltage measurements may be taken for purposes of characterizing each DAC **106-110**. Generally, the more voltage measurements taken for each DAC **106-110**, the more precision there is injected into characterizing the variability among the DACs **106-110**. For example, with more voltage measurements for each DAC **106-110**, the non-linearity of the DACs **106-110** can be better taken into account.

[**0021**] Though a monitor is illustrated in **FIG. 1**, it should be understood that the disclosed techniques may be applied to a DAC interface for a television, rather than a DAC interface for a monitor. Stated another way, the voltage output level from DACs for a television such as an S-video output, rather than a VGA output for a monitor, may be characterized in accordance with the disclosed techniques. Stated yet another way, based on the disclosed techniques, any DAC of a video subsystem or graphics controller of a computer system may be characterized.

[**0022**] The foregoing disclosure and description of the various embodiments are illustrative and explanatory thereof, and various changes in the measurement techniques, storage techniques, color management software, DACs, components, circuit elements, circuit configurations, and signal connections, as well as in the details of the illustrated circuitry and software and construction and method of operation may be made without departing from the spirit and scope of the invention.

We claim:

1. A method of characterizing a plurality of digital-to-analog converters for a plurality of color channels of a video subsystem of a computer system, the method comprising the steps of:

driving the plurality of digital-to-analog converters with a set of predetermined input digital values;

measuring a plurality of output analog voltages of the plurality of digital-to-analog converters in response to the driving step; and

storing a plurality of digital characterization values corresponding to the plurality of output analog voltages.

2. The method of claim 1, wherein the set of predetermined input digital values comprises only a maximum input digital value for the plurality of digital-to-analog converters.

3. The method of claim 1, wherein the plurality of digital characterization values are stored in a non-volatile memory associated with the video subsystem.

4. The method of claim 1, the storing step comprising the step of:

storing a set of digital characterization values for each digital-to-analog converter of the plurality of digital-to-analog converters.

5. The method of claim 4, wherein the set of digital characterization values comprises only a single digital characterization value for each digital-to-analog converter.

6. The method of claim 1, wherein the set of predetermined input digital values comprises a plurality of input digital values for each digital-to-analog converter of the plurality of digital-to-analog converters.

7. The method of claim 1, wherein the plurality of digital characterization values comprise a plurality of digital representations of the plurality of analog output voltages.

8. The method of claim 1, wherein the plurality of digital characterization values comprise a plurality of digital values corresponding to a mathematical model for the plurality of analog output voltages.

9. The method of claim 1, wherein the measuring step is performed with a precision termination load resistor.

10. The method of claim 1, wherein the plurality of digital characterization values represents a plurality of transfer functions for the plurality of digital-to-analog converters.

11. A computer system, comprising:

a processor; and

a video subsystem coupled to the processor, the video subsystem comprising:

a plurality of digital-to-analog converters for a plurality of color channels of the video subsystem;

a video connector coupled to the plurality of digital-to-analog converters for connection to a monitor; and

a non-volatile memory storing a plurality of digital characterization values for the plurality of digital-to-analog converters.

12. The computer system of claim 11, wherein the plurality of digital characterization values represent a plurality of transfer functions for the plurality of digital-to-analog converters.

13. The computer system of claim 11, wherein the plurality of digital characterization values comprise a plurality of digital representations for a plurality of analog output voltages measured for the plurality of digital-to-analog converters by driving the plurality of digital-to-analog converters with a set of predetermined input digital values.

14. The computer system of claim 11, wherein the plurality of digital characterization values comprises only a single digital characterization value for each digital-to-analog converter of the plurality of digital-to-analog converters.

15. The computer system of claim 11, further comprising:

color management software executable by the processor to perform color correction based on the plurality of digital characterization values.

16. A video subsystem for a computer system, comprising:

a plurality of digital-to-analog converters for a plurality of color channels for the video subsystem; and

a non-volatile memory storing a plurality of digital characterization values for the plurality of digital-to-analog converters.

17. The video subsystem of claim 16, wherein the plurality of digital characterization values comprise a plurality of digital representations for a plurality of analog output voltages measured for the plurality of digital-to-analog converters by driving the plurality of digital-to-analog converters with a set of predetermined input digital values.

18. The video subsystem of claim 16, wherein the plurality of digital characterization values comprises only a single digital characterization value for each digital-to-analog converter of the plurality of digital-to-analog converters.

19. The video subsystem of claim 16, wherein the plurality of digital characterization values represent a plurality of transfer functions for the plurality of digital-to-analog converters.

20. A method of characterizing a plurality of color channels of a video subsystem of a computer system, the method comprising the steps of:

driving the plurality of color channels with a set of predetermined input digital values;

measuring a plurality of output analog signals of the plurality of color channels in response to the driving step; and

storing a plurality of digital characterization values corresponding to the plurality of output analog signals.

21. The method of claim 20, wherein the plurality of digital characterization values are stored in a non-volatile memory associated with the video subsystem.

22. The method of claim 20, wherein the video system comprises a graphics controller.

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