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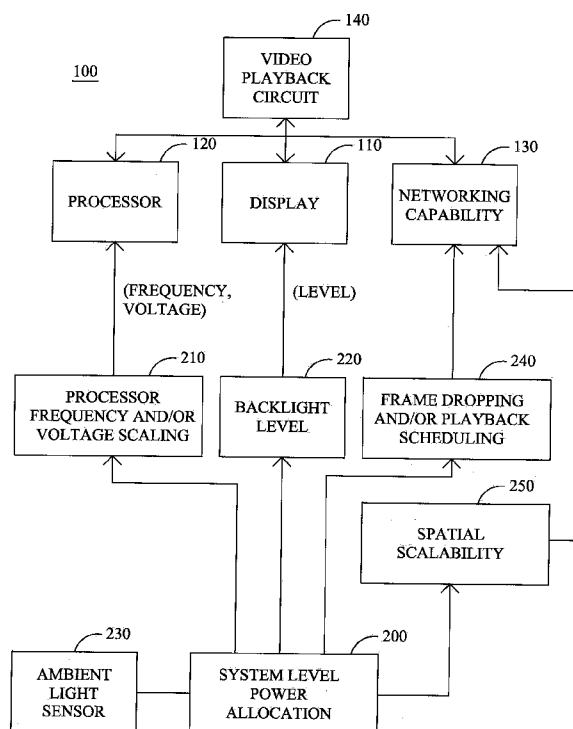
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(54) Title: A BATTERY POWERED DEVICE

FIG. 1



(57) Abstract: A battery powered device including power management includes a display, a processor, a video decoder, a networking circuit, and a power allocation process. The power allocation process modifies the power used to process a video by jointly selecting a lower power usage based upon selectively dropping frames to be decoded by the video decoder, and selectively decreasing the illumination of a backlight of the display.

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DESCRIPTION

TITLE OF INVENTION: A BATTERY POWERED DEVICE

TECHNICAL FIELD

The present invention relates generally to a system for
5 power management of devices with limited available power.

BACKGROUND ART

Battery powered televisions and mobile devices are
commonly used device for receiving and/or displaying video
10 content. The audio-video content is typically in the form of an
encoded communication over a broadcast channel, such as over
the air, a cable connection, or other data connection. In some
cases, the audio-video content is stored locally with the device.
The video content is displayed on the display and the audio
15 content is provided through associated speakers. Unfortunately,
the presentation of the audio-video content to the viewer has a
limited duration due to the power capabilities of the associated
battery.

What is desired is a device capable of displaying audio-
20 video content with effective power management.

SUMMARY OF INVENTION

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One embodiment of the present invention discloses a battery powered device including power management comprising: (a) a display; (b) a processor; (c) a video decoder; (d) a networking circuit; (e) a power allocation process that
5 modifies the power used to process a video by jointly selecting a lower power usage based upon: (i) selectively dropping frames to be decoded by said video decoder; (ii) selectively decreasing the illumination of a backlight of said display.

The foregoing and other objectives, features, and
10 advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

15 BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 illustrates system level power allocation.

FIG. 2 illustrates quality as a function of frame rate.

FIG. 3 illustrates power consumption for various components.

20 FIG. 4 illustrates power consumption at different brightness levels.

DESCRIPTION OF EMBODIMENTS

Referring to FIG. 1, a video device 100, such as a battery
25 powered television or a battery powered mobile device, includes

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a display 110 which may be used to display video content. The display 110 typically includes a backlight which consumes a significant amount of power that limits the playback duration of video content. The device 100 may also include speakers to provide an audio output. The audio-video content may be received by an antenna. The audio-video source may be, for example, a digital video player, a VHS player, a cable connection, an Internet connection, a wireless connection, a memory card, storage internal to the device 100, or any other source.

The device 100 may also include a processing unit 120, such as a general purpose processor or a special purpose processor. The processing unit (processor, video decoder) 120 consumes a significant amount of power which limits the playback duration of video content. The device 100 may also include networking capability (networking circuit) 130 to receive streaming audio-video content, such as from a local storage device or a network based source. The networking capability 130, such as cellular or wireless, also consumes a significant amount of power which limits the playback duration of video content. The power allocation (power allocation process) 200 may select enabling the networking capability 130. Also in many cases a video playback circuit 140, which may be included within the processing unit 120, is used to decode and play the video on the display 110; that is, a video decoder is

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included together with the processing unit 120. In addition the video playback circuit 140 consumes a significant amount of power which limits the playback duration of video content.

The device 100 may include a system level power allocation 200. The power allocation 200 may adjust the characteristics of the significant power consuming devices used in conjunction with video presentation in a manner that maintains a sufficient image quality while extending the duration over which the video may be presented. The power allocation 200 may select a processor frequency and/or voltage scaling 210. The processor frequency and/or voltage scaling 210 may adjust the power consumed by the processor 120 by modifying its operating frequency and/or scaling the voltage used by the processor. As the voltage being used by the processor and/or the operating frequency is reduced, the amount of power consumed by the processor 120 is likewise reduced. This reduction in the power usage (lower power usage) may be used to increase the playback duration of video content.

The power allocation 200 may select a backlight level (illumination) 220 for the display 110. The backlight level 220 may be selected such that a lower backlight emission is used by the display 110. In some cases, the backlight level 220 may be selected, at least in part, based upon an ambient light sensor (ambient sensor) 230. The display 110 may be dimmer when the ambient light level is lower, while maintaining a relatively good

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video image quality. As the backlight level being used by the display 110 is reduced, the amount of power consumed by the display 110 is likewise reduced. This reduction in the power usage may be used to increase the playback duration of video content.

In the case of liquid crystal displays, the transmission of the liquid crystal layer may be increased while the backlight is reduced, from what it would have otherwise been. In this manner, the brightness of the display may remain relatively high while maintaining a similar image quality for the video content. This may likewise reduce power consumption during video content playback.

The power allocation 200 may select frame dropping and/or playback scheduling 240. Often hardware decoding is used for the video decoding, which requires substantial power. Each frame of the video has an associated deadline, and each frame must be decoded and displayed before its deadline to ensure a smooth video playback. The video may be analyzed off-line or on-line, and the frequency of the processor 120 may be scaled depending the complexity. In addition, it may be desirable to drop video frames (the playback may thus display the same frame for an extended duration), either at the server or at the device 100. This may result in relatively good video quality, while reducing the power usage.

The power allocation 200 may select spatial scaling 250.

The spatial scaling may select among different resolutions of the video. The lower the resolution, the less power that is used by the device 100.

The power allocation 200 may switch to a lower bitrate stream for the same video content. Typically the lower the bitrate, the less power is used by the device 100.

The system level power allocation 200 may use a joint function to determine the appropriate settings for the different primary power usage device to selectively increase the video playback duration. The length of the playback may be selected based upon the anticipated available power (available battery power). Also, the duration of the video may be used as the basis to adjust the power usage to ensure sufficient power will be available for the entire video duration.

To determine the appropriate settings, a quality score as a function of video frame rate ($u(f)$) may be determined. As the frame rate decreases compared to a nominal frame rate, the subjective quality of the video decreases. A normalized Mean Opinion Score (MOS) variation with frame rate is generally independent of the quantization parameter. A subjective quality as a function of video frame rate may be defined as:

$$MOS(f) = Q_{\max} \frac{1 - e^{\frac{-cf}{f_{\max}}}}{1 - e^{-c}}$$

The system may define a utility function which maps the MOS to a range of [0,1]. The utility function which provides a

quality score as a function of frame rate may be :

$$u_i(f) = \frac{MOS(f)}{100}$$

The system may further categorize the video content into two categories (low motion, high motion). FIG. 2 illustrates the quality function (MOS) as a function for these two cases. Additional categories (e.g. medium motion) may be utilized, as desired. The classification of a video content into low motion and high motion may be done using any suitable technique. In particular the system may utilize the motion vector information from bit stream during decoding process to make the classification.

The energy required as a function of processor frequency and voltage may be empirically determined. The significant power consuming components of the overall system may include: idle power, display power, decoding power, networking/streaming power. To identify the power consumption of each of these components a series of measurements on a device as an off-line step where one component is added at a time may be performed. The measurements may be repeated at different CPU frequencies/voltages.

FIG. 3 illustrates the power consumption at different CPU frequencies for a smart phone device. The measurements are fitted to a parametric model or are stored as a look up table. A

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model fit may be obtained by modeling the dynamic power P as a function of the frequency g and voltage V as:

$$P = E * g * V^2$$

where E is a constant.

5 Additional measurements may be conducted for each component at different levels. As an example display brightness can be set to different levels, the video with different frame rates for the same content can be received by streaming and played back. As an example FIG. 4 illustrate measurements
10 with display brightness set to two different levels. Then energy consumption at different CPU frequencies ($e(f_i, b_j, g_k)$) for different frame rates and different backlight levels is measured.

$$L(i) = [l_1 \ l_2 \ l_3 \dots l_R]$$

An optimal playback pattern for a given frame rate (f) may be characterized. Given a frame rate f , the system can
15 utilize a power aware playback scheduling technique to determine the optimal frame playback pattern. A summary of a playback technique may be as follows.

Playback Pattern: Let $L(i) = [l_1 \ l_2 \ l_3 \dots l_R]$ be a playback pattern vector where

$$l_k = \begin{cases} 0 & \text{if frame } fr_k \text{ is dropped} \\ 1 & \text{otherwise} \end{cases}$$

Optimized Playback Scheduling: For each playback pattern $L(i)$, there is:

Expected power consumption $P_{L(i)}$

Expected video quality distortion $D_{L(i)}$

Determine optimized playback pattern by minimizing the cost function:

$$\min_{L(i)} [D_{L(i)} + \lambda P_{L(i)}]$$

5 Expected Power Consumption: Let the processor support frequencies $[g_1, g_2, \dots, g_T]$ and voltages $[V_1, V_2, \dots, V_Q]$ then dynamic power used at a frequency g_j and voltage V_q is $P_{j,k} = E * g_j * V_q^2$. Then $P_{L(i)}$ may be determined by considering contribution from each frame, i.e.

$$P(L(i)) = \sum_k P(L(i))_k$$

10 Expected Distortion: Expected Distortion $D_{L(i)}$ can be modeled for frame playback pattern $L(i)$ as follows

$$D_{L(i)} \approx D_0 - \sum_k \Delta D(l_k)$$

D_0 is the distortion if none of the frames is played back,

$\Delta D(l_k)$ is expected reduction in distortion if frame k is not
15 dropped in playback pattern $L(i)$ and decoded before its playback deadline.

Backlight/Brightness function: The user can set the brightness level to any setting in the set $[b_{\min}, \dots, b_{\max}]$. Let the user selected brightness be indicated by b_u . The system may define a
20 quality function $u_2(b_u, b_{\text{mod}})$ as a function of the user selected brightness b_u and the device selected modified brightness level b_{mod} . One example quality function can be defined as:

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$$u_2(b_u, b_{\text{mod}}) = \min\left(1, \frac{b_{\text{mod}}}{b_u}\right)$$

In other embodiments alternative quality functions may be used in place of the above quality function u_2 . The quality functions may be selectable by a user.

5 Given a user selected brightness level, the system will select a modified brightness level depending upon the user selected level and the present energy state and optimization based on the quality function. The power allocation system will supply the modified brightness level to the backlight selection
10 unit. The backlight selection unit will select the level used for the backlight, and hence actual power consumption, based on the modified brightness level and the image content. Depending upon the content, the final level sent to the backlight may be lower than that corresponding to the modified brightness
15 setting. In such cases, the actual energy consumption will be less than predicted based on the modified brightness level. This lower energy consumption will influence the system operation through feedback which tracks the battery state.

20 The system level power allocation may be characterized as follows:

B =Available battery charge information (in mAh).

T =Media playback duration (in minutes) (or user specified duration for the total media playback).

L =Ambient light level information.

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The allocation computes the budget for battery charge consumption per time unit (e.g. minute):

$$R = \frac{B}{T}$$

This module may use the following pre-computed information.

foreach CPUFrequency [$g_1, \dots, g_r$]

foreach Brightness [$b_1, \dots, b_m$]

foreach FrameRate [$f_1, \dots, f_p$]

Store ($u_1(f_i, g_k)$)

Store ($u_2(b_j, g_k)$)

Store ($e(f_i, b_j, g_k)$)

end

end

Where $u_1(f_i, g_k)$ is the value of the utility function at the frame rate f_i and at CPU frequency g_k , $u_2(b_j, g_k)$ is the value of the utility function at the brightness setting b_j and at CPU frequency g_k , $e(f_i, b_j, g_k)$ is the estimated energy consumption (in mAh/min) at the frame rate f_i , at the brightness setting b_j and at CPU frequency g_k . This may be obtained as described in the energy as a function of processor frequency and voltage previously described.

At certain CPU frequencies a particular frame rate video may not be playable in real-time. In this case the utility function is assigned a zero value ($u_1(f_i, g_k) = 0$). In some

embodiments additionally the energy estimate may be assigned infinite (or very high) value to avoid selecting that operating point ($e(f_i, b_j, g_k) = \infty$).

In some embodiment the table may be computed on the fly. Further more this table may be modified in real-time for the particular media being played back by utilizing a feedback regarding the actual energy consumption during playback and comparing it with the estimated energy consumption. Then the technique utilizes the input information to search the values of $e(f_i, b_j, g_k)$ and select the frequency and brightness/backlight which maximizes the utility function (quality function) while meeting the energy constraint:

```

 $u^s = 0$ 
foreach CPUFrequency [ $g_1, \dots, g_T$ ]
  foreach Brightness [ $b_1, \dots, b_m$ ]
    foreach FrameRate [ $f_1, \dots, f_p$ ]
      if ( $e(f_i, b_j, g_k) < R$ )
        if ( $u_1(f_i, g_k) * u_2(b_j, g_k) > u^s$ )
           $f^s = f_i$ 
           $b^s = b_j$ 
           $u^s = u_1(f_i, g_k) * u_2(b_j, g_k)$ 
        end
      end
    end
  end
end

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The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in

the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

5 The invention being thus described, it will be obvious that the same way may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the
10 scope of the following claims.

 One embodiment of the present invention discloses a player (battery powered device), comprising: optimizing means for optimizing a playback pattern of a video in accordance with a predetermined cost function by indicating, for each frame of
15 the video included in the video, whether or not the frame is dropped, the playback pattern specifying playback scheduling of the video; and playing means for playing the video, without playing a dropped frame(s) that the playback pattern optimized by the optimizing means indicates to drop.

20 Some embodiments of the present invention disclose the player, wherein the optimizing means optimizes the playback pattern by specifying the play back pattern which minimizes the predetermined cost function.

 Some embodiments of the present invention disclose the

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player, wherein the optimizing means optimizes the playback pattern in accordance with the predetermined cost function which is a sum total of an expected power consumption value and an expected distortion value, the expected power consumption value indicating an amount of power to be consumed by the player, the expected distortion value indicating distortion in quality of playing of the video, the distortion being expected to be caused by playing the video without playing the dropped frame(s).

5

CLAIMS

1. A battery powered device including power management comprising:

(a) a display;

(b) a processor;

(c) a video decoder;

(d) a networking circuit;

(e) a power allocation process that modifies the power used to process a video by jointly selecting a lower power usage based upon:

(i) selectively dropping frames to be decoded by said video decoder;

(ii) selectively decreasing the illumination of a backlight of said display.

2. The device of claim 1 wherein said power allocation process further jointly selecting said lower power usage based upon at least one of a frequency and voltage scaling for said processor.

3. The device of claim 1 wherein said power allocation process further jointly selecting said lower power usage based upon playback scheduling.

4. The device of claim 1 wherein said power allocation

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process further jointly selecting said lower power usage based upon spatial scalability.

5 5. The device of claim 1 wherein said power allocation process further jointly selecting said lower power usage based upon guaranteed video playback for a selected duration based upon available battery power.

10 6. The device of claim 1 wherein said power allocation process further jointly selecting said lower power usage based upon selectively enabling said networking circuit.

15 7. The device of claim 1 wherein said video decoder is included together with said processor.

 8. The device of claim 1 wherein said illumination is further based upon an ambient sensor.

20 9. The device of claim 1 wherein said power allocation process further jointly selecting said lower power usage based upon a lower bitrate for said video.

 10. The device of claim 1 wherein said power allocation process is based upon a quality function.

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11. The device of claim 10 wherein said quality function is selectable by a user.

12. The device of claim 11 wherein said quality function is generally based upon

$$MOS(f) = Q_{\max} \frac{1 - e^{\frac{-cf}{f_{\max}}}}{1 - e^{-c}}.$$

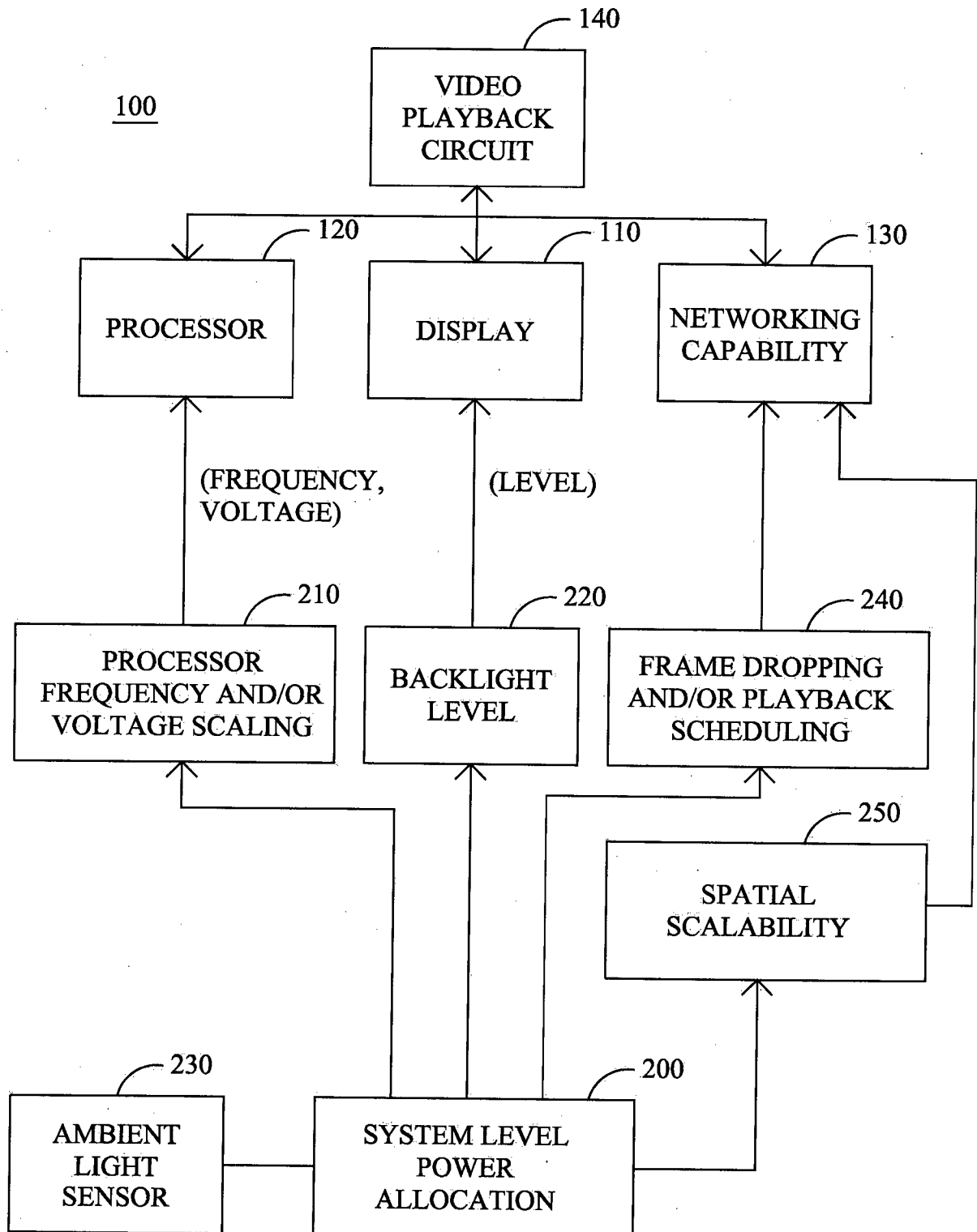
13. The device of claim 1 wherein said power allocation process is based upon a classification of said video as a low motion video and high motion video.

14. The device of claim 10 wherein said quality function is based upon a backlight level of said display.

15. The device of claim 14 wherein said quality function is generally based upon

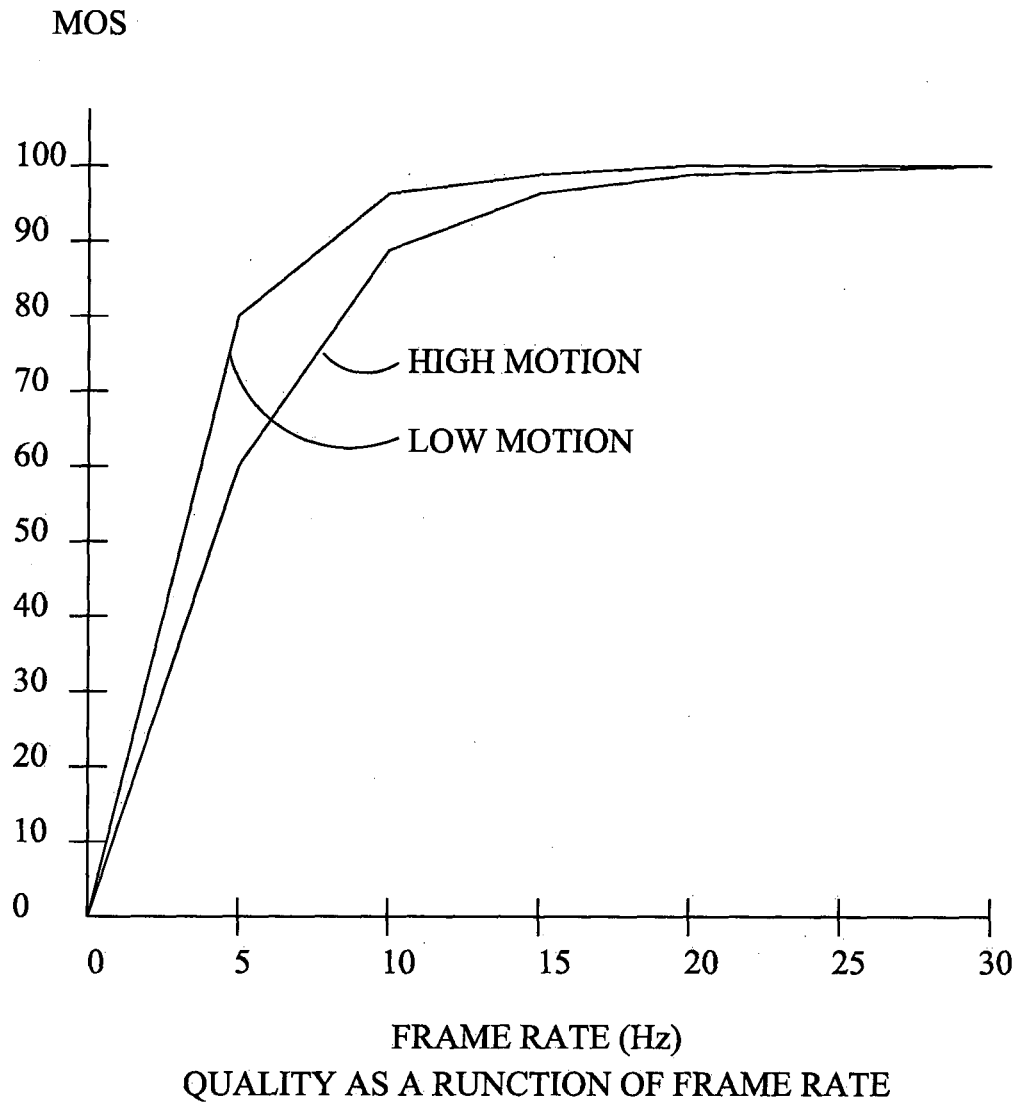
$$u_2(b_u, b_{\text{mod}}) = \min\left(1, \frac{b_{\text{mod}}}{b_u}\right).$$

FIG. 1



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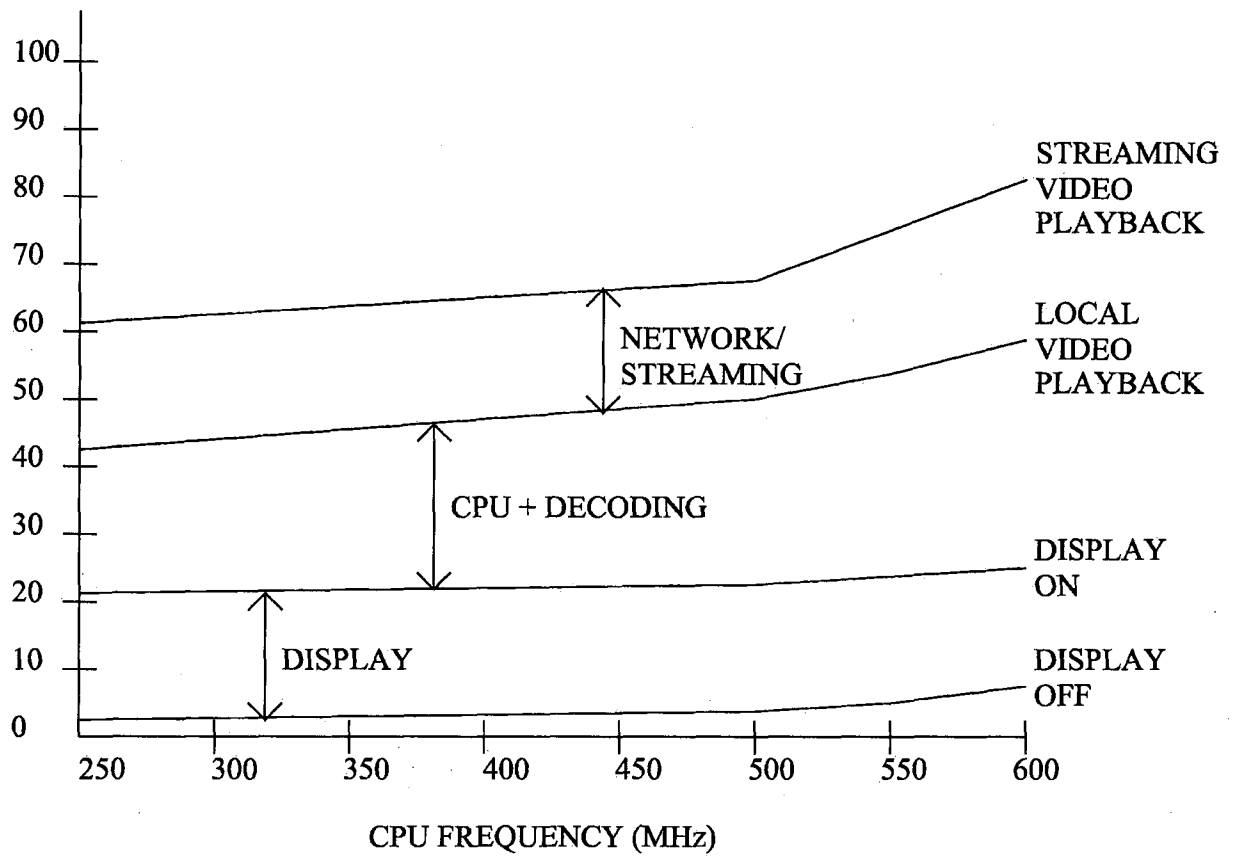
FIG. 2



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FIG. 3

BATTERY
CHARGE
USED (mAh)

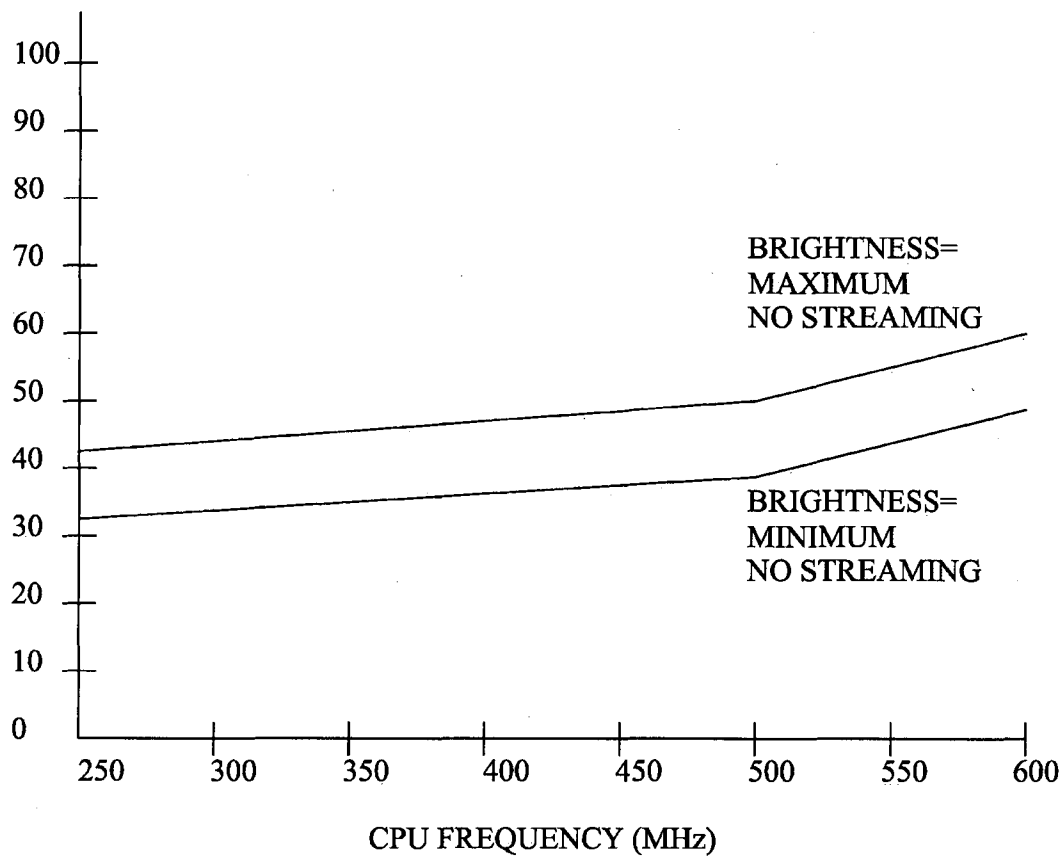


POWER CONSUMPTION MEASUREMENTS ON A
MULTIMEDIA DEVICE FOR VARIOUS COMPONENTS

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FIG. 4

BATTERY
CHARGE
USED (mAh)



POWER CONSUMPTION MEASUREMENTS AT
DIFFERENT BRIGHTNESS LEVELS

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060199

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. G06F1/32 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. G06F1/32

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2012
 Registered utility model specifications of Japan 1996-2012
 Published registered utility model applications of Japan 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2008-311712 A (Mitsubishi Electric Corporation), 25 December, 2008 (25.12.08), Par. No. [0029]; Figs. 5, 9 (No Family)	1, 3-5, 13 2, 6-9 10-12, 14-15
Y	JP 2007-219835 A (Toshiba Corporation), 30 August, 2007 (30.08.07), Par. Nos. [0047], [0049]; Fig. 7 & US 2007/0188429 A1 & EP 1821194 A2 & CN 101025655 A	2, 7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search

14.06.2012

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060199

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2009-130860 A (Toshiba Corporation), 11 June, 2009 (11.06.09), Par. No. [0021] (No Family)	9
A	JP 2000-357024 A (Sony Corporation), 26 December, 2000 (26.12.00), Par. Nos. [0107] - [0124], [0128]; Fig. 7 & US 6834354 B1 & EP 1115051 A1 & WO 2000/077599 A1	10-12, 14-15