State-based Battery Peak Power Management for Space Constrained Systems

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State-based Battery Peak Power Management for Space Constrained Systems

ABSTRACT

Battery powered systems such as AR/VR/MR devices are space constrained due to which power monitoring of individual subsystems of such devices is not possible. Peak load management without such monitoring is a difficult task. This disclosure describes peak load power management techniques that utilize a power estimate for the battery in current operating conditions and a lookup table of different power states in various subsystems. The overall power requirement for the system in the current power state is compared with the power estimate. Brownouts are avoided by performing suitable state transitions for each subsystem such that the total power required by the system is less than the estimated peak power.

KEYWORDS

- Peak load
- Power management
- Space-constrained device
- Virtual reality (VR)
- Augmented reality (AR)
- Mixed reality (MR)
- Head-mounted device (HMD)

BACKGROUND

Consumer electronics, such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) devices, are used in a variety of applications across domains such as gaming, healthcare, manufacturing, education, etc. Many consumer electronics (e.g., AR/VR/MR devices) deliver experiences to users using one or more batteries and/or battery-powered
In battery-powered systems, peak load management is a challenging task, due to the lack of accurate knowledge about the peak loads that can be supported by the battery over time. A conventional approach for peak load power management involves fixed threshold based throttling to reduce the load on the battery as per the state of charge (SOC). However, this method can lead to shorter run times, even though the battery is capable of supporting more peak power. To overcome this problem, the threshold used for throttling needs to be regularly adjusted to account for the changes in the battery impedance changes, e.g., due to battery degradation and environmental conditions. Battery impedance increases at lower state of charge (e.g., less than 20%), at lower temperature, and as the battery ages (experiences higher numbers of charge/discharge cycles).

A constantly adjusted threshold is available via the battery Pmax/turbo mode feature available in battery fuel gauges. The Pmax/turbo feature in battery fuel gauges can generate reliable estimates for peak power that can be used by the system without browning out (voltage rail collapsing). For systems to use this approach, a power consumption monitor for each of the subsystems is a prerequisite. Individual system power consumption readings are added up to ensure that the total system consumption is less than the estimated battery peak power. However this approach is infeasible for many electronic devices, such as AR/VR/MR devices, due to space constraints which imply that there is not sufficient space for subsystem level power consumption monitors.

DESCRIPTION

This disclosure describes techniques for peak load power management in space-constrained systems. The techniques utilize the battery fuel gauge estimated peak power and the
different power states in various subsystems. Each of the subsystems is designed with different power states, which can be triggered from an external source such as a microcontroller unit (MCU).

The need for subsystem level power monitors is fulfilled by using a subsystem level power table and a total system power table. A power table is developed for each subsystem to record the power requirement at each power state. The subsystem level power tables are utilized to create a total system power table that indicates the power requirements of each subsystem for each power level and also the power requirement for the entire system.

In the illustrative example in Table 1, the system consists of four subsystems. Each subsystem has six power states, the power requirement for each subsystem in each power state is listed in the total system power table. Table 1 is for illustration only; different systems may have any number of subsystems, e.g., 5 subsystems, 10 subsystems, etc. and different numbers of power states.

<table>
<thead>
<tr>
<th></th>
<th>SubSystem1</th>
<th>SubSystem2</th>
<th>SubSystem3</th>
<th>SubSystem4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>State5</td>
<td>871</td>
<td>918</td>
<td>273</td>
<td>3613</td>
<td>5675</td>
</tr>
<tr>
<td>State4 (80% of State 5)</td>
<td>696.8</td>
<td>734.4</td>
<td>218.4</td>
<td>2890.4</td>
<td>4540</td>
</tr>
<tr>
<td>State3 (60% of State 5)</td>
<td>522.6</td>
<td>550.8</td>
<td>163.8</td>
<td>2167.8</td>
<td>3405</td>
</tr>
<tr>
<td>State2 (40% of State 5)</td>
<td>348.4</td>
<td>367.2</td>
<td>109.8</td>
<td>1445.2</td>
<td>2270</td>
</tr>
<tr>
<td>State1 (20% of State 5)</td>
<td>174.2</td>
<td>183.6</td>
<td>54.6</td>
<td>722.6</td>
<td>1135</td>
</tr>
<tr>
<td>State 0 (10% of State 5)</td>
<td>87.1</td>
<td>91.8</td>
<td>27.3</td>
<td>361.3</td>
<td>567.5</td>
</tr>
</tbody>
</table>

Table 1: System power table for different states
The estimated peak power from the battery changes per the battery state of charge, temperature, and/or battery ageing. The peak power that can be drawn from the battery is estimated reliably by the battery gauge. The peak power estimate from the battery fuel gauge and the total system power table is evaluated to move the system to a suitable state per the process illustrated in Figure 1.

![Figure 1: Automatically adjusting power levels to avoid brownouts](image)

The power requirement of the entire system as read from the total system power table is compared with the peak power estimate from the battery gauge. If the estimated system power requirement is greater than the estimated peak power that can be drawn, all the subsystems are moved to the next lower power stage.

In the illustrative example of Table 1 and Figure 1, State5 is the default state where each subsystem is running with full functionality. Per Table 1, the total power required by the system in this state is 5675 mW. If the estimated peak power from the battery is less than 5675 mW, all subsystems are moved to State4. The system continues in State4, until the estimated peak power from the battery drops below 4540.

Automatic adjustment of power levels as described herein avoids brownouts by ensuring that the total power required by the system is less than the estimated peak power that can be
supported by the battery in current conditions. Additional controls can be provided to ensure that state changes are monotonic.

CONCLUSION

This disclosure describes peak load power management techniques that utilize a power estimate for the battery in current operating conditions and a lookup table of different power states in various subsystems. The overall power requirement for the system in the current power state is compared with the power estimate. Brownouts are avoided by performing suitable state transitions for each subsystem such that the total power required by the system is less than the estimated peak power.