



SURFACE VEHICLE INFORMATION REPORT

J3311™

MAR2026

Issued

2026-03

Vehicle Platform Power Management

RATIONALE

Increasingly stringent economy and range regulations are forcing increased efficiency in electrified vehicles (EVs) and Internal Combustion Engine (ICE) applications. Increasing load from electrical devices, including vehicles equipped with driving automation system hardware, vehicle controls, and user interfaces, has forced complexity in vehicle electrical systems, driving weight and costs as maximum current draw of modern vehicles exceeds 200 A on the 12-V system. Leveraging experience from power management of personal portable devices, Vehicle Platform Power Management (VPPM) seeks to leverage concepts such as Advanced Configuration Power Interface (ACPI), Mission Profiles, dynamic variable voltage, and advanced control algorithms to reduce electrical load and manage electrical components in an efficient manner.

1. SCOPE

This SAE Information Report is applicable to all types of automotive Electrical/Electronic (E/E) system architectures. It is important to develop a standard approach to commanding differentiable vehicle power policies from a centralized host Electronic Control Unit (ECU) location to applicable and capable ECUs and devices for maximum energy and thermal efficiency while creating and maintaining reuse across the ecosystem. Thus, adoption at a global level will enable efficiencies in product development and validation between all Original Equipment Manufacturers (OEMs) and the supply chain while maximizing reuse of ECUs and devices including respective power policies and capabilities between OEM vehicle systems.

The definition of the Central System Power Manager (CSPM), VPPM Agent, Element Descriptor Tables, Element Descriptor Files, reference diagrams, and feature definitions are considered applicable and in scope for definition and standardization under SAE J3311.

Software libraries and deployment, power state transition definition, vehicle network, protocol, component E/E topology/structure, electrical implementation schematics, and cybersecurity of transmission and storage of data are considered out of scope for definition and standardization under SAE J3311.

1.1 Purpose

This document introduces how to define a power management framework following ACPI system principles but designed for the vehicle architecture. The need for such a system is driven by the increasing complexity and reliance on electronic systems in modern vehicles and the ever-larger amounts of energy they consume. This document seeks to address this challenge by defining at a high level the interfaces, components, and power states required to apply vehicle platform power management policies.

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 UEFI Publications

Advanced Configuration and Power Interface (ACPI) Specification (Version 6.4, January 2021). Available at https://uefi.org/htmlspecs/ACPI_Spec_6_4_html/.

3. DEFINITIONS

3.1 ADVANCED CONFIGURATION POWER INTERFACE (ACPI)

An open industry specification that establishes industry-standard interfaces enabling OS-directed configuration, power management, and thermal management of desktop, mobile, and server platforms.

3.2 VEHICLE POWER POLICY

Vehicle system of systems level mapping of vehicle power states to respective ECU and Device power states that describe how to power mode while transitioning into various vehicle operating states.

3.3 VEHICLE E/E ARCHITECTURE

Vehicle system of systems definition that includes signal and power mapping between various compute nodes and devices.

3.4 CENTRAL COMPUTE

Dedicated complex and high power compute with memory and advanced processing capability that enables a software defined vehicle through the consolidation and centralization of various vehicle control functions and user interfaces into a centralized unit.

3.5 ELECTRONIC CONTROL UNIT (ECU)

Dedicated computing units with capability to store states in memory that oversee vehicle functions ranging from engine management to climate control

3.6 ZONAL CONTROLLER (ZC)

Dedicated computing units with capability to store states in memory that are derived from the consolidation of various ECUs within specific physical regions or domains of the vehicle to enable more efficient software defined vehicle developments.

3.7 DEVICE

Sensors and actuators tasked with specific operations within a vehicle system with embedded microcontroller power management capability or a capability with power management by managing parent ECU.

3.8 CENTRAL SYSTEM POWER MANAGEMENT (CSPM)

The crucial and differentiable software component that enables the mapping and command/control of the vehicle power states based on the element descriptor table to the various ECU and Device power states VPPM agents.

3.9 VEHICLE PLATFORM POWER MANAGEMENT (VPPM) SUBSYSTEM

Responsible for hosting the element descriptor table that enables the CSPM to command and control the respective ECUs and Devices based on the vehicle power policy state change.

3.10 ELEMENT DESCRIPTORS

The stored data within an ECU or Device that describe the various attributes enabling command and control for the CSPM.

3.11 ELEMENT DESCRIPTOR TABLES

The central repository of all element descriptors available within the entire vehicle E/E architecture within the VPPM subsystem.

4. DOCUMENT CONTENT

4.1 Background

The ACPI specification is designed to allow operating systems to control the amount of power given to each device that is attached to or part of the computer system. This can help extend battery life for portable computers, reduce noise from cooling fans, and reduce overall power consumption. The specification defines a flexible and extensible interface that provides a standard way to integrate power management features throughout a Personal Computer (PC) system, including hardware, operating system (OS), and application software. This allows systems to turn off peripheral devices and/or enter into lower power states to conserve energy when not in use.

The concepts behind ACPI for PC can be adapted to the automotive industry; particularly for electric and hybrid vehicles, where power management and energy conservation are critical aspects of the vehicle's operation and cost. This would allow vehicles to manage power more efficiently, improve fuel efficiency and/or battery life, and provide a better user experience in terms of vehicle utility and extended range. For example, a vehicle could shut down nonessential systems when the battery is low or manage the power given to different ECUs and devices based on the current usage conditions. Additionally, this could also include features like automatic adjustment of the vehicle's power settings based on the driver's preferences or the current driving conditions, similar to how a computer adjusts its power settings based on the current workload and power source.

Therefore, the main goal of this specification is to define a standards-based, flexible, and extensible interface that provides a standard way to integrate advanced power management features across the vehicle platform, ensuring system responsiveness when needed and prioritizing safety and functionality.

4.2 Vehicle Platform Power Management Specification

The objective of the VPPM is to define an open ACPI-like interface for vehicles to holistically define power management policies across the entire vehicle platform and thus be able to efficiently manage the power, performance, and thermal status of the subsystems. This is done while adhering to the Quality of Service (QoS) and usability goals imposed by the vehicle components' operating conditions.

Figure 1 illustrates a modern vehicle E/E architecture with a combination of zonal compute nodes, ECUs and devices, and a central compute unit all linked through the vehicle's main communications backbone, where vehicle-level power management can be implemented with software deployed through the central compute by adopting ACPI principles.

Similar to ACPI, where the PC OS acts as the "power management policy owner" determining the optimal power state for a device in the PC platform at any given moment, the central compute in a vehicle would fulfill a similar role in the example outlined in this specification by hosting the CSPM service (the CSPM service can be hosted on any capable ECU in an OEM implementation).

However, the central compute is not the only component of a vehicle-level power management system. The various ECUs and devices are the components that carry out the power policies designated by the central compute. As such, multiple interfaces must be defined to enable the central compute to discover, configure, and control E/E resources, enabling it to manage power at the vehicle platform level.

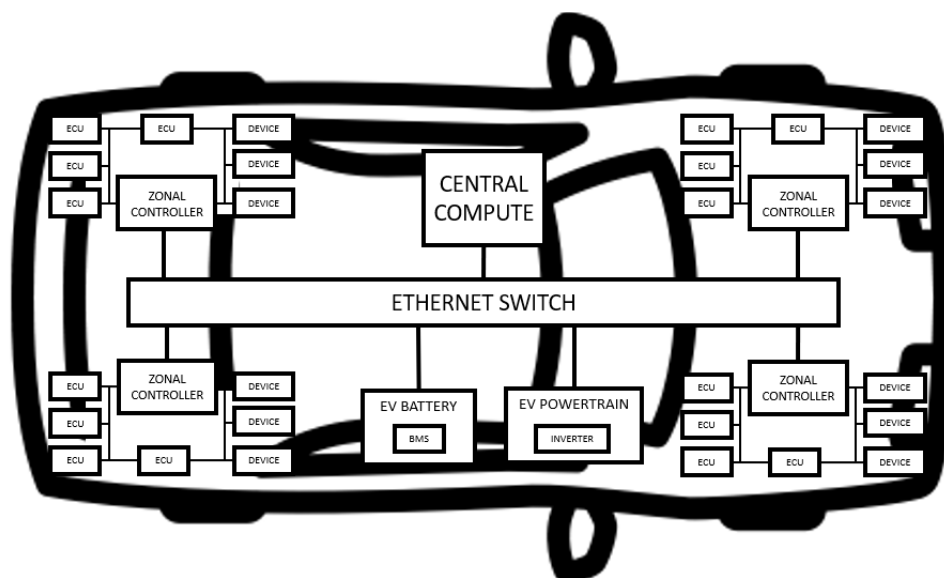


Figure 1 - Example of a modern vehicle architecture

Figure 2 offers a simplified representation of VPPM components (see dashed boxes) within this specification's example vehicle architecture, which will be further introduced and detailed in subsequent sections. Besides better managing the power consumption at the vehicle level, it is also crucial for power management policies to be adaptable to varying operational scenarios. For example, an automated driving system/dedicated vehicle for passenger service operating in the urban environment of San Francisco, which typically involves lower speeds, will have distinct power management requirements compared to one cruising on the highways around Dallas. Vehicles should actively monitor and adjust power consumption across different levels of their operational hierarchy.

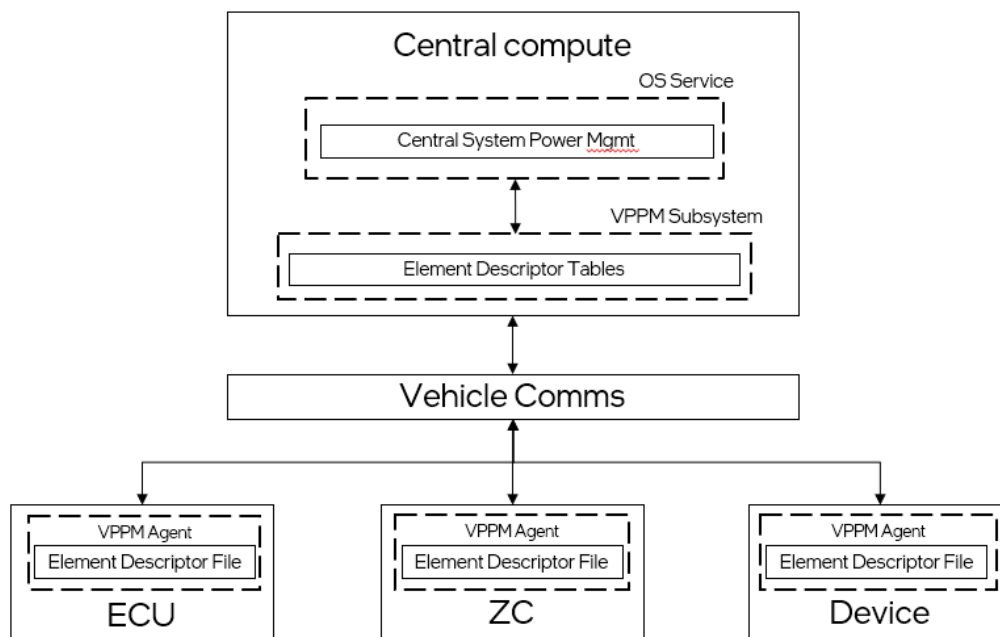


Figure 2 - Schematic overview of vehicle platform power management components

A simplified high-level state machine diagram as shown in Figure 3 illustrates how the CSPM monitors the vehicle for Vehicle State Change triggers and broadcasts a change Vehicle Power State to the VPPM Agents of the ECUs and Devices within the vehicle network, enabling each ECU and Device to update their respective power states accordingly. There is a feedback mechanism as well for success or fail with state indication of transition so that the CSPM is aware of every ECU and Device power state.

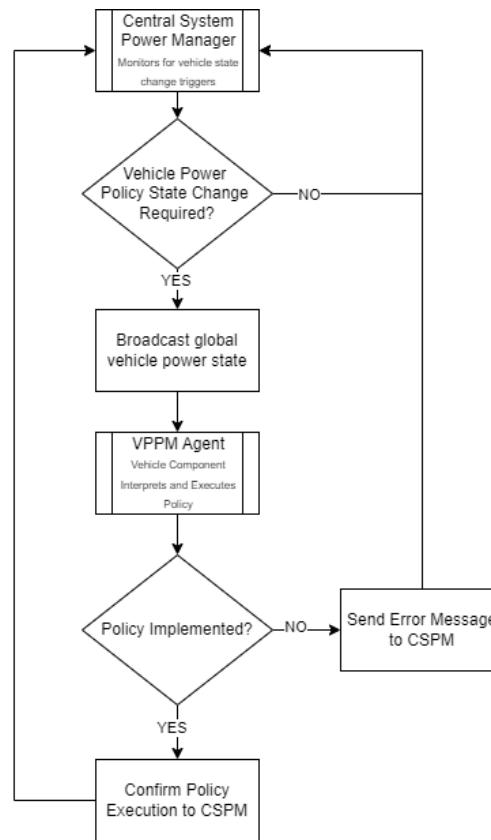


Figure 3 - Example power state machine

Additionally, many other use cases can arise for different power management policies. One example would be to tailor the power management policies to the health conditions of the vehicle's hardware. New hardware is capable of functioning at its maximum capacity, yet with time it becomes increasingly susceptible to the effects of voltage, current, and thermal stress, which calls for a more cautious approach to power management. Older hardware is often characterized by a rise in leakage current during low power or sleep states, impacting both battery performance and system dependability. By integrating considerations of hardware aging into the power management policies, the CSPM can modify its strategies to accommodate the hardware's evolving performance characteristics. Such proactive adjustments lead to more precise battery life predictions and facilitate more seamless power mode transitions, enhancing the overall reliability and efficiency of the vehicle's power management system.

4.3 Central Compute

The primary function of the central compute in the context of this specification's example of a VPPM system is to monitor and manage power usage at the vehicle level while also communicating power management strategies to ECUs and Devices connected throughout the vehicle's network. The key elements of this specification that are encompassed by the central compute include the VPPM Subsystem (including Element Descriptor Tables) and the CSPM operating as an OS service.

4.3.1 VPPM Subsystem

The VPPM Subsystem is the central compute's main interface that provides the tables which contain information about the hardware components of the vehicle platform and their power management descriptors and features (i.e., Element Descriptor). These data structures are used to enumerate the devices and ECUs during discovery, along with their capabilities such as current and supported power states, state-change latencies, wake-up characteristics, and more. As such, this interface should be OS independent, hardware design agnostic, and defined with a high degree of interoperability, extensibility, and flexibility to ensure seamless communication and efficient power management across different vehicle topologies, hardware, operating systems, and platform implementation within the vehicle. As shown in Figure 4, the CSPM State Mapping of a Vehicle Power Policy is linked to the relevant Vehicle, ECU, and Device Power State descriptor data in memory (additional components and states are expected in a typical implementation).

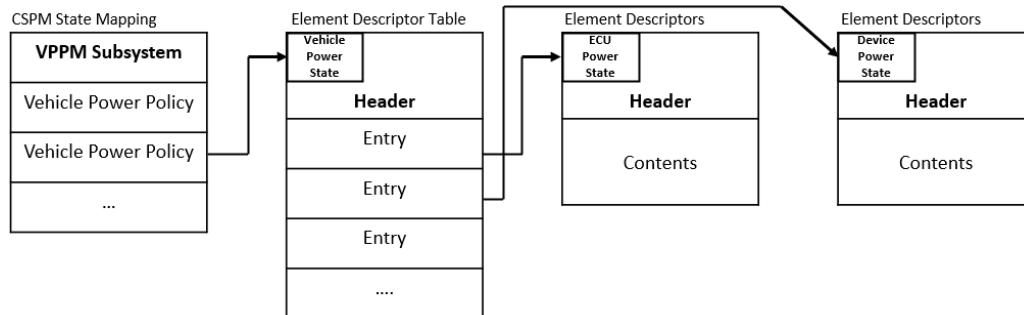


Figure 4 - Example of a CSPM and VPPM subsystem pointer and tables

4.3.2 Central System Power Management

The CSPM is a key component of the central compute that leverages the VPPM Subsystem's interfaces to define and manage power policies at the vehicle level, akin to the OS-directed configuration and Power Management in the ACPI specification. It is responsible for making informed decisions about power state transitions, considering vehicle energy consumption information, system policies, user preferences, safety considerations, and device specifications. It also has the capability to power down noncritical systems to preserve energy.

The CSPM plays a pivotal role in coordinating power management at the vehicle level. It does this by continuously monitoring vehicle-level state transitions defined within the VPPM Subsystem's Vehicle Power Policies and broadcasts the optimal Vehicle Power State throughout the system to the receiving VPPM Agents hosted in various ECUs and Devices. The VPPM Subsystem's element descriptor tables identify the corresponding ECU and Device power states that are best suited for each Vehicle Power Policy, ensuring that the CSPM has the capability to confirm proper operating Power States as well as relevant wake-up requirements or deterministic behavior of the power state transitions.

The management and execution of power policies are realized via functions and methods implemented within the CSPM to discover ECUs and devices' characteristics, get the current power state, or set a given power state. Once a decision to change power states is made, the CSPM communicates this decision to the ECUs and devices (e.g., via a function that sends a packet over the automotive Ethernet network) and receives confirmation of the executed power state at the ECU and device level.

It's important to note that, unlike the VPPM Subsystem, the functionality and implementation of the CSPM is hardware and architecture dependent and operating system specific. Therefore, it is not covered in this specification. The CSPM OS Service should be executed from any capable ECU that is operational and available for the longest duration to ensure proper vehicle power sequencing and control, not necessarily the Central Compute as described in the example in this document.