i.MX31 SOM Windows® CE Power Management

Application Note 353

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Abstract

Basic Windows® CE power management is built into Logic Product Development's i.MX31 System on Module (SOM) Windows CE platform solution. The basic power management is implemented through system states that draw from 100 mW to 1.5 W in power. Although the basic power management provided may be fully sufficient for some customer products, it may be augmented to provide a finer level of control over the power states of the system per the product's design criteria. These criteria should be use-case driven and will be typically implemented in a System Management Module for the system.

REVISION HISTORY

REV	EDITOR	DESCRIPTION	APPROVAL	DATE
A	Hans Rempel	Initial Release	MAA	12/21/07

1 Introduction

Although the i.MX31 processor has multiple power management capabilities, it may not be apparent how their control is exposed from within the Windows CE operating system environment. While some features are automatically controlled by the operating system components, others may be controlled by custom software or user actions. This application note gives an overview of how user level actions, operating states, and software Application Program Interface (API) calls relate to the i.MX31 power management capabilities as implemented on the i.MX31 SOM's Windows CE Board Support Package (BSP).

2 Operating System Modes

The Windows CE operating system implements two base-level operating system modes: Normal Operating Mode and Suspend Mode. In Normal Operating Mode, the system is available to respond to input of some kind and usually appears to be "on" to the user. In Suspend Mode, the system is not available for immediate response and usually appears to be "off" to the user.

2.1 Normal Operating Mode

Normal Operating Mode is the state of the system immediately after powering on and initializing the operating system. It is also the state that the system typically enters upon exit from Suspend Mode.

With a properly configured OS build and appropriate baseboard design, Normal Operating Mode power draw from the SOM (with all peripherals active) should be about 1 W when the system is idle and 1.5 W when the system is processing tasks.

2.1.1 CPU States

In Normal Operating Mode, the Windows CE task scheduler automatically controls the mode of the CPU based on scheduled events and hardware interrupts. For example, when not running a task, the system CPU is put into a reduced power state. When running a task, the system CPU is in an active state applicable to the performance requirements of the task(s).

The i.MX31 SOM BSP uses the processor's "Run" mode when actively processing a task in Normal Operating Mode. The processor's "Wait Mode" is used when not actively processing a task in Normal Operating Mode. The effective power savings realized from implementing this run-time mode switching is about 700 mW when the scheduled task load is less than 5% of the processor's bandwidth.

2.1.2 Peripheral States

A Windows CE system in Normal Operating Mode can implement different system-wide power states by controlling the power levels of the system peripherals during run-time. These peripheral power states can either be independently controlled by a custom software implementation (typical for a closed-system) or can be controlled by a combination of the Windows CE power management driver and custom software (typical of an open system). For example, a product may need to reduce backlight brightness by 50% after 30 seconds of inactivity while in Normal Operating Mode—this is typically implemented by a custom application or driver that directly controls the backlight per activity timer information.

2.2 Suspend Mode

Suspend Mode is the state of the system when the APIs "GwesPowerOffSystem()" or "SetSystemPowerState(POWER_STATE_SUSPEND)" are called. On a headed Windows CE device implementing an unmodified explorer shell, the user can activate Suspend Mode by selecting the task bar item "Start->Suspend."

Suspend Mode is also referred to as the “Instant-Off, Instant-On” Mode—referring to the relatively fast entry and exit of the Suspend Mode (typically less than 1 second).

Suspend Mode exits to Normal Operating Mode when the CPU receives an unmasked interrupt—typically due to a user action (like a tap on a touch screen), an expired timer, or an indication of received data by a peripheral.

With a properly configured OS build and appropriate baseboard design, Suspend Mode power draw from the SOM should be less than 100 mW.

2.2.1 CPU States

In Suspend Mode, the processor is put into the “State Retention” mode. In this mode, the i.MX31 processor puts the system RAM into self-refresh mode and retains register settings.

The “State Retention” mode consumes from 0.2 mW to 3.3 mW more than “Deep Sleep” mode (the next lower-power processor mode), but has the advantage of not having to restore processor subsystems (typically requires a system reset).

2.2.2 Peripheral States

In Suspend Mode, peripherals are powered down per driver power-down routines and recovered by power-on routines. These routines are called automatically by the Windows CE operating system in response to a user or software command to put the system into Suspend Mode.

If a hardware peripheral does not have a device driver responsible for powering the peripheral down (or does not implement appropriate power control), it is likely that the peripheral is maintained in a fully-on power state during Windows CE Suspend Mode.

The amount of time a system takes to enter or exit Suspend Mode is almost entirely dependent upon the speed of the device driver power routines.

3 System Power Management

Each product implementing the i.MX31 SOM will have usage-driven requirements that should dictate the over-all system approach to power management. To understand how the system should achieve the usage-driven requirements, it is helpful to create a table that lists the relationship between user, operating system, and hardware terms. An example of such a table is shown below:

State Name	User State	OS Mode	Hardware Settings	Entry Criteria
D0	Running	Normal Operating	CPU and peripherals fully powered	System reset; Power button pressed when in D3 or D4.
D1	Idle	Normal Operating	LCD backlight reduced to 50% brightness	No user activity for > 30 seconds.
D2	Waiting	Normal Operating	LCD backlight reduced to 25% brightness, Ethernet NDIS D3.	No user activity for > 5 minutes.
D3	Standby	Suspend	CPU in State Retention, all peripheral supplies powered off.	Power button pressed while in D0-2; No user activity for > 20 minutes.
D4	Off	Off	Only RTC powered	Battery <10% capacity; In D3 for > 4 hours.

Depending on the complexity of the system, each state or mode (i.e., User, OS, or Hardware) may require further explanation in a separate listing. For example, User State “Running” could be described in terms of user activities possible, while a Hardware Setting “HW1” could be created that is defined to mean that the CPU and all peripherals are fully powered.

Some products may only have two User States (e.g., Running and Off). For these, it is possible that no customizations need to be made to the default operating system behavior. However, many products implement a more complex array of User States, requiring some customization to the system’s default behavior with respect to power management.

3.1 System Management Module

For systems that require customization of the default behavior of the operating system, a “system management” module is typically implemented in order to customize system behavior. Some level of custom control can be done in an application, but a driver is usually the format of choice because of low-level hooks into other operating system components that facilitate system initialization, power management, and interface to other applications and drivers.

Some functionality that a System Management Module could implement includes:

- Management of power button events
- Activity timer setup and monitoring
- Power supply power-off after graceful software shutdown
- Miscellaneous power control for peripherals without dedicated device drivers
- Communication with companion processor (typically related to power events)
- IOCTL interface that exposes appropriate functionality to other applications and drivers
- Other system management tasks (e.g., registry flushing, RTC synchronization, in-field update assistance)

Note on “pm.dll”:

Windows CE provides a power management driver “pm.dll” that implements a defined D0...4 power management state framework in which each driver’s power states are explicitly mapped to a system power state (D0 through D4). This implementation works best for fully defined products that have open application environments. Because the SOM that Logic Product Development provides can act as a component in a variety of different embedded systems (i.e., the products are not fully defined and are not typically open to end-user software development), it is recommended that a system-specific power management module be implemented by the product vendor as opposed to the “pm.dll” component.

3.2 Peripheral Power Control

3.2.1 Ethernet Power Control

On the i.MX31 SOM, the Ethernet peripheral consumes the largest amount of power after the processor. Controlling Ethernet power states effectively can make a significant difference in the power draw of the system.

Power control for the Ethernet subsystem uses NDIS IOCTL (“DeviceIoControl()”) calls to set Ethernet driver power states during runtime. NDIS defines its own power states as NdisDeviceStateD0...3. These NDIS power states are explicitly mapped to Ethernet driver power states to provide four different levels of power and performance operation of the interface.

In system Suspend Mode, the Ethernet driver automatically puts the Ethernet peripheral into NdisDeviceStateD3. In system Normal Operating Mode, it is the responsibility of custom software to set the desired power state of the Ethernet peripheral. A System Management Module running on the system can determine which state the Ethernet subsystem should be put into based on product-specific factors (e.g., user menu selection, activity timeout, cable status).

On the i.MX31 SOM, possible power savings with intelligent control of the Ethernet subsystem during runtime can be as high as 376 mW.

3.2.2 Atlas Power Supply Control

The power rails on the i.MX31 SOM are largely provided by the Atlas Power Management Interface Controller (PMIC) and controlled by system software. The Atlas PMIC has four switching power supplies and fifteen linear regulators provided for system peripheral and core power supply sourcing.

The driver "lpd_imx31_mc13783" provides a Windows CE software control mechanism to the Atlas PMIC. The driver's registry settings have bit fields provided so that the OS designer can specify how the Atlas PMIC should control its linear and switching regulators when the system is put into Suspend Mode.

The lowest Suspend Mode power settings for the PMIC power supplies are the default settings in the registry. However, for a custom product it may be the case that, for example, the SDIO interface should remain powered during Suspend Mode. In this case (and other cases where a peripheral supply regulator should remain powered), the OS designer should apply the appropriate registry settings so that the Suspend Mode state of the PMIC power supplies is correct for the product. The registry file comments provide a reference for how to set the correct values.

3.2.3 Off-SOM Peripheral Power Control

Many products implement peripheral devices on the SOM's application baseboard that require independent power control. Power control for off-SOM peripherals can either be done in a driver dedicated to the interface, in a System Management Module (referenced above), or purely in hardware (gated by another SOM-based signal). For example, one common item implemented on the baseboard, or elsewhere on the system, is a backlight inverter; the power to this interface is typically gated by an LCD power signal and further gradient control is provided by custom software.

Some peripherals that are not typically gated by SOM-based software include:

- Real Time Clock
- Low power microcontroller (system controller)

One general design criteria for controlling the power of off-SOM peripherals in Suspend Mode is that the custom software should "gracefully" shut down the peripheral so that it is fully recoverable by the same software module when returning to Normal Operating Mode.

4 Summary

The Freescale i.MX31 processor has advanced power management capabilities enabling a variety of different power modes as dictated by system software. While Logic Product Development's Windows CE BSP for its i.MX31 SOM implements basic low-power system operation, the user can manipulate other power and performance factors specific to the requirements of their product.

For further support with system power management for a product based on the i.MX31 SOM, please contact platformsupport@logicpd.com .