TEXAS INSTRUMENTS

TMS320DM368 Power Consumption Summary

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ABSTRACT

This application report discusses the power consumption of the Texas Instruments TMS320DM368 digital media System-on-Chip (DMSoC). Power consumption on the DM368 device is highly application-dependent; therefore, a spreadsheet that estimates power consumption is provided along with this document. To obtain good results from the spreadsheet, realistic usage parameters must be entered (see Section 2.1). The low-core voltage and other power design optimizations allow these devices to operate with industry-leading performance, while maintaining a low power-to-performance ratio.

The data presented in the accompanying spreadsheet was measured from strong units, representative of devices at the maximum end of power consumption for production units. No production units will have average power consumption that exceeds the spreadsheet values; therefore, the spreadsheet values can be used for board thermal analysis and power supply design as a maximum long-term average.

The spreadsheet discussed in this application report can be downloaded from the following URL: http://www.ti.com/lit/zip/SPRABB4.

Table 1. Typical Activity

Sample	Core Voltage	Configuration	ARM Frequency	DDR Frequency	Power (mW) [1]			
					Core	IO18	IO33	Total
DM368	1.35 V	Static	0	0	93	3	0	95
		Standby	24	24	104	3	0	107
		ARM+DDR	432	340	333	51	0	384
		Deep-Sleep	0	0	102	3	0	105

[1]
- Static power consumption varies with process, temperature and voltage. All of the readings shown here are taken at room temperature (25°C). In standby power consumption, both static and clock-in power is considered. In ARM + DDR power consumption, ARM is running at 432 MHz, DDR2 is configured and running at 340 MHz with 50% utilization, 50% writes and 50% switching.
- Power for I018 and IO33 includes the analog as well as digital power rail.

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1 Model Activity

1.1 Activity-Based Models

Power consumption for the TMS320DM368 can vary widely depending on the use of on-chip resources. Therefore, you cannot estimate power consumption accurately without an understanding of the components of the DMSoC in use and the usage patterns for those components. By providing the usage parameters that describe how and what on the DMSoC is being used, accurate consumption numbers can be obtained for power-supply and thermal analysis.

This model breaks down power consumption into two major components: baseline power and activity power. Using this model, various applications that use the DMSoC differently can get accurate predictions across the spectrum of possible power consumption on the DM368.

1.2 Baseline Power

Baseline power consumption is power that is independent of chip activity such as static power (leakage), phase-locked loop (PLL), oscillator power, DDR2 DLL consumption, and clock tree power to various subsystem components (e.g., SCR) that cannot be turned off via the on-chip power management module. While independent of chip activity, baseline power is dependent on the device operating frequency, voltage, and temperature. Therefore, you can affect baseline power only by changing the PLL(s) output frequency, the core voltage, or the operating temperature.

1.3 Activity Power

Activity consumption is power that is consumed by active parts of the DMSoC: CPU(s), EMIF, peripherals, etc. Activity power is independent of temperature, but dependent on voltage and activity levels. In the spreadsheet, activity power is separated by the major modules within the device. Therefore, the individual module power consumption can be estimated independently; this helps with tailoring power consumption to specific applications. The parameters used to determine the activity level of a module are frequency, utilization, read/write balance, bus size, and switching probability. Note that not all parameters apply to all modules.

- Frequency: The operating frequency of a module or the frequency of external interface to that module.
- Status: Indicates whether the module is in an enabled or disabled state.
- % Utilization: The relative amount of time the module is active or in use versus off or idle.
- % Write: The relative amount of time (considering active time only) the module is transmitting versus receiving.
- Bits: The number of data bits being used in a selectable-width interface.
- % Switch: The probability that any one data bit will change state from one cycle to the next.

Not all modules include all of the parameters.

1.4 Modules

The DM368 power estimation spreadsheet contains the following modules with adjustable parameters:
- CPU (ARM926EJ-S™ Core)
- MPEG-JPEG Co-Processor (MJCP)
- High-Definition Video Image Co-Processor (HDVICP)
- Video Processing Sub-System (VPSS) (display(VPBE) and capture(VPFE))
- MultiMedia Card/Secure Data (MMC/SD)
- Key Scan
- Power Management and Real Time Clock Subsystem (PRTCSS)
- DDR2/mDDR Memory Controller
- Asynchronous External Memory Interface (AEMIF)
- Ethernet Media Access Controller (EMAC)
- Analog-to-Digital Converter (ADC)

- Voice Codec
- Universal Serial Bus (USB)
- Universal Host Port Interface (UHPI)
- Multichannel Buffered Serial Port (McBSP)
- Serial Peripheral Interface (SPI) (0-4)
- Inter-Integrated Circuit (I2C)
- Timer (0-3)
- Watchdog Timer (WDT)
- Pulse Width Modulator (PWM) (0-3)
- Universal Asynchronous Receiver/Transmitter (UART) (0 and 1)
- General-Purpose Input/Output (GPIO)
- Enhanced Direct Memory Access (EDMA3)
- Real Time Output (RTO)

2   Using the Power Estimation Spreadsheet

The power estimation spreadsheet involves entering the appropriate usage parameters as input data in the spreadsheet. Cells that are designed for user input are white in color. The following steps explain how to use the spreadsheet:

1. Choose the case temperature for the estimated power
2. Fill in the appropriate module use parameters

The spreadsheet takes the provided information and displays the details of power consumption for the chosen configuration.

As the spreadsheet is being configured, the settings are checked for conflicts, e.g., peripheral clock frequency out of allowed range, etc. For best results, enter the information from left to right starting at the top and moving downward.

2.1   *Choosing Appropriate Values*

The frequency and bit user values are determined by design and it will be clear what the correct values to enter are. For some modules, the frequency field is used to input the data rates (for instance, UART, EMAC, etc). In order to choose appropriate values, you need a good understanding of read/write balance, bit switching required estimation, and utilization of the user application. You should also keep in mind the pin multiplexing configuration for the device to avoid enabling mutually exclusive peripherals/configurations at the same time. For available peripherals and their configuration, see the device-specific data manual.

2.1.1   Utilization

For modules except CPU (ARM926EJ-S Core) and HDVICP, utilization is simply the percentage of time the module spends doing something useful, versus being unused or idle. For these peripherals, there are not various degrees of use, so the value is just an average over time. For example, the EMIF performs reads and writes one-quarter of the time and has no data to move for the other three-quarters of the time (though it continues to perform background tasks like refresh); this would be 25% utilization.

For peripherals with I/O, utilization can be estimated by comparing used bandwidth with theoretical maximum bandwidth. If, for example, an application must transfer 160 Kb/s via the I2C port, with a theoretical 400 Kb/s maximum, the I2C port utilization would be about 40%. In some cases, the max bandwidth allowed may be dependent on the device frequency; factor this while calculating the utilization if doing the estimation at different device frequencies.

System level issues may also reduce utilization. Though the spreadsheet accepts 100% utilization for all peripherals, this is not possible in reality. As concurrency in data movement increases and/or throughput requirements on high bandwidth modules (EDMA, VPSS, etc.,) increases, overall peripheral activity is throttled back due to bottlenecks created at various common end points. In such cases, peripherals might not achieve 100% utilization; therefore, you should enter individual module utilization numbers keeping this overall limitation in mind.

2.1.2   % Writes

Peripherals that transmit as much data as they receive have 50% writes; the spreadsheet assumes the remaining 50% of the time is spent on reads. In some applications, peripherals move data in only one direction, or have a known balance of data movement. In these cases, % writes should be changed to 0%, 100%, or the known ratio as appropriate for the cases when the DMSoC is reading all the time, writing all the time, or a combination of the two, respectively. Otherwise, 50% is a typical number that should be used.

2.1.3   % Switching

Random data has a 50% chance any bit will change from one cycle to the next. Some applications may be able to predict this chance using prior information about the data set. If there is a property of the algorithm that allows prediction of the bit changes, the application-specific probability can be used. All other applications should use the default number of 50%.

2.2   *Peripheral Enabling and Disabling*

As mentioned previously, the DM368 device provides the capability to disable modules that are not being used via the power sleep controller (PSC). When a peripheral is disabled, its clock is turned off reducing the power consumption of the device.

The spreadsheet accommodates this power saving feature by including fields from which a peripheral can be specified as disabled or enabled.

If a module is not used for a given application, then it is recommended to keep it in disabled state.

It is possible that the module is kept enabled but has no activity. To achieved this, program the % utilization and/or the frequency fields to a value of 0, then the numbers in the module's row will be indicative of the power consumed by clocking the module.

For CPU (ARM926EJ-S Core) spreadsheet provides four states:

*   Sleep Mode: Sleep Mode is a special power-down mode in which all device clocks are stopped, but the internal oscillators are on. For more details, see the *TMS320DM368 Digital Media System-on-Chip (DMSoC) Data Manual* (SPRS668).
*   Deep Sleep: Deep Sleep Mode is a special power-down mode in which all device clocks are stopped and the internal oscillators are powered down. Registers and software are preserved. Therefore, upon recovery, the program can continue from where it left off with minimal overhead involved. For more details, see the *TMS320DM368 Digital Media System-on-Chip (DMSoC) Data Manual* (SPRS668).
*   No-Activity: Indicates the ARM state when it is executes NOP instruction.
*   Typical Activity: Indicates the ARM state when it is executes instruction other than NOP instruction.

3   Using The Results

The intent of the power estimation spreadsheet is to provide estimates of the upper bounds in an application-specific loading and peripheral utilization scenario. The measured units were selected to be a strong unit at the maximum end of power consumption for production units. No production units will have average power consumption that exceeds the spreadsheet values; therefore, the spreadsheet data can be considered maximum average power consumption; the actual observed power may vary. That is, transient currents may cause power to spike above the spreadsheet value for a small amount of time; however, over a long period, the observed average consumption will be below the spreadsheet value. The spreadsheet value can be used for board thermal analysis and power supply design as a maximum long-term average.

3.1 Adjusting I/O Power Results

I/O power is dependent not only on the device and activity, but also the load being driven. For loads with CMOS inputs, the power required to drive the trace dominates, and is a better measure of load than the number of inputs or lumped load capacitance. If the target system has very different I/O loading, scale the spreadsheet results either up or down to compensate. For this reason, the spreadsheet allows you to specify the approximate load on the I/O pins for each module by using the trace length field. This parameter is used to adjust the reported I/O power numbers.

4 Example

The following examples demonstrate how to choose appropriate values for a particular application. These values can be imported into the spreadsheet by clicking the appropriate macro button.

4.1 Basic Configuration(s)

The *Static* macro button reports the static power for the device, when the MXI/CLKIN is cut off and voltage is applied to the various core and I/O rails.

The *Standby* macro button reports the power consumed with the 24 MHz CLKIN. PLL1 and PLL2 are powered down/disabled and the system is operating in bypass mode with the CLKIN as the system clock. The ARM is in the *wait for interrupt* sleep mode and all peripherals are disabled.

The macro button *Deep Sleep Mode* reports the power consumed when all device clocks are stopped and the internal oscillators are powered down.

NOTE: In *Static* configuration, a *finite* current component is shown on the I/O rails (V_{DDS18} and V_{DDS33}), these values are system dependent and will differ (could be lower or higher) based on the state of pull up or pull downs and load on the device I/O lines.

4.2 Sample Application(s)

This is one example that explains how power consumption summary is achieved for a custom use case scenario by enabling modules used in that scenario, their mode and utilization. The Sample Application macro button reports the power consumed by one of the use case scenarios where the configurations in the power spreadsheet are mentioned below.

The details of the peripherals and their operating conditions used in this scenario are:
- Voltage: 1.35 V (C_{VDD})
- Strong Process
- Case temperature: 50°C
- CLKIN: 24 MHz
- ARM: Typical activity that involves configuring peripheral and other house keeping activities polling for response from HDVICP
- HDVICP: Enabled for H264,720P-30 fps encoding operation
- EMAC: Enabled , 100 Mbps, 100% Utilization, 40% Switching
- VPFE: Enabled and running for YCC16 720P-30 fps video input from CCDC image sensor to DDR
- DDR: Enabled, 50% utilization 50% writes, 50% switching

All other modules are not used and disabled.

Table 2 shows the approximate power estimation in this scenario calculated using the power spreadsheet.

Table 2. Sample Power Consumption Summary

Core Voltage (V)	CPU Frequency (MHz)	Core	IO18	IO33	Total	Case Temperature (°C)
1.35	300	730	37	56	823	50

5   Limitations

The current implementation of the power estimation spreadsheet has the following limitations:

• All the measurements have been done with ARM sourcing clock from PLL2 and other modules sourcing clock from PLL1.

• All measurements have been performed with a 24 MHz CLKIN provided by an external oscillator. The spreadsheet does not provide a capability of estimating power based on a different CLKIN value.

6   References

• *TMS320DM368 Digital Media System-on-Chip (DMSoC) Data Manual* (SPRS668)

• *TMS320DM36x Digital Media System-on-Chip (DMSoC) ARM Subsystem User's Guide* (SPRUFG5)