Application Report
SPRABL4A—September 2011

Power Consumption Summary for KeyStone TCI66x Devices

Communications Infrastructure

Abstract

This document discusses estimating the power consumption of Texas Instruments KeyStone Digital Signal Processors (DSP) using a provided device-specific power spreadsheet.

The power consumption of the device is highly application-dependent, therefore, the provided power spreadsheet allows a number of variables to be set according to the intended application to calculate accurate estimates of device power consumption. This spreadsheet can be used to model power consumption to assist in power supply design, thermal design, etc. To obtain good results from the spreadsheet, realistic usage parameters must be entered.

The data found in this document and in the accompanying spreadsheet were measured from devices at the maximum end of the power consumption range for production devices. No production devices will have average power consumption that exceeds the spreadsheet values; therefore, the spreadsheet values may be used for board thermal analysis and power supply design as a maximum long-term average.

Contents

1 Activity-Based Models . . . 2
1.1 Baseline Power . . . 2
1.2 Activity Power . . . 2
2 Spreadsheet Parameters . . . 3
2.1 Power Domains Details . . . 3
2.2 Device Modules/Peripherals . . . 3
3 Using the Power Estimation Spreadsheet . . . 4
3.1 Choosing Appropriate Values . . . 4
3.2 Peripheral Enabling and Disabling . . . 6
4 Using the Results . . . 7
4.1 Adjusting I/O Power Results . . . 7
4.2 Spreadsheet Layout and Details . . . 7
4.3 Current vs. Power Variable Option . . . 7

RapidIO is a registered trademark of RapidIO Trade Association.
All other trademarks are the property of their respective owners.

1 Activity-Based Models

Power consumption for the device can vary widely depending on the use of on-chip resources. Therefore, power consumption cannot be estimated accurately without an understanding of the components of the device in use and the usage patterns for those components. By providing the usage parameters that describe what is being used on the device and how it is being used, accurate power consumption values can be obtained for power supply and thermal analysis. Expected power consumption for worse-case utilization can be determined by choosing usage parameters closest to the real-use case.

The power spreadsheet divides the power consumption into two major components: baseline power and activity power.

1.1 Baseline Power

Baseline power consumption is the power consumed that is independent of chip activity, such as:

- Static leakage power
- Core power
  - Clock tree
  - Internal memory
  - On-chip module power
  - Etc.

Baseline power is highly dependent on voltage, temperature, and DSP frequency.

1.2 Activity Power

Activity power consumption is power that is consumed by all active parts of the device:

- CorePac
- Enhanced direct memory access (EDMA3)
- Peripherals
- And so on

The activity power is independent of temperature, but highly dependent on the activity levels of the DSP, EDMA3, peripherals, etc. In the power spreadsheet, activity power is separated by the major modules/peripherals within the device. Therefore, the individual module/peripheral power consumption can be estimated independently. This helps with tailoring power consumption to specific applications.

Module/peripheral activity power consumption includes some necessary EDMA3 and DSP activity used to transfer data on-chip and off-chip when required. The power consumption associated with EDMA3 and DSP activity has been minimized to show only power consumption with respect to the module/peripheral tested.

2 Spreadsheet Parameters

The spreadsheet provides configurable parameters that allow the estimation of power consumption based on configured usage parameters. To ensure realistic results, verify that the spreadsheet is configured accurately. For more details, see Section 3.1.

The parameters are as follows:

- **Frequency:** Specifies the operating frequency of a module/peripheral or the frequency of the external interface to that module.
- **Modes:** Selects the peripheral-specific configuration mode.
- **Status:** Specifies whether a peripheral is *Enabled* and configured for use, or *Disabled* and unconfigured.
- **% Utilization:** Specifies the relative amount of time the module is active or in use versus off or idle.
- **% Write:** Specifies the relative amount of time (considering active time only) the module is transmitting versus receiving.
- **Bits:** Specifies the number of data bits to be used in a selectable-width interface.
- **Lane:** Specifies the number of lanes used by that interface.
- **% Switching:** Specifies the probability that any one data bit on the relative data bus will change state from one cycle to the next.

2.1 Power Domains Details

Power domains and associated clock domains within the device (except the Always On domain) can be disabled or enabled by software. When a power domain is disabled, the peripherals and memories in that domain are put to sleep to reduce leakage dissipation, and the peripherals are held in reset and clock-gated, reducing the baseline and activity power consumption of the device.

The spreadsheet that accompanies this application report allows you to disable or enable a power domain in the model by selecting *Disabled* or *Enabled* status for the peripheral in the drop down menu of the status column.

For more information on power domains that can be disabled and the Power Sleep Controller, see the device-specific Data Manual and the *Power Sleep Controller (PSC) for KeyStone Devices User Guide* (SPRUGV4).

2.2 Device Modules/Peripherals

For information on modules and peripherals available on a device, see the device-specific Data Manual.

3 Using the Power Estimation Spreadsheet

The use of the power estimation spreadsheet involves entering the appropriate usage parameters as input data in the spreadsheet. The following steps show the general flow:

1. Choose the appropriate DSP operating frequency: 1200 MHz to 400 MHz.
2. Choose the case temperature for which you want to estimate power: 0°C to 100°C.
3. Enable the appropriate peripherals used for your application including the mode, frequency, and bus width for that peripheral, if applicable.
4. Enter the appropriate peripherals' or modules' % utilization, % writes, and % switching values.

For best results, enter the information from left to right, starting at the top and moving downward. As the spreadsheet is being configured, the settings are checked for conflicts. For example, it checks to see if the specified clock frequency is within the allowed range.

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

3.1 Choosing Appropriate Values

Acceptable values are determined by design and the correct values to enter will be clear.

You can disable unused modules/peripherals in the spreadsheet by selecting the Disabled tab in the column labeled Status. To choose the appropriate values, you need a good understanding of the read/write balance, bit switching required estimation, and utilization of the user application.

3.1.1 % Utilization

For modules other than the DSP, utilization is simply the percentage of the time the module spends doing something useful, versus being unused or idle. For these peripherals, the value is just the average over time. For example, if the DDR3 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 refreshes), this would be considered 25% utilization.

The DSP utilization is not as straightforward, because there are varying degrees of use for the DSP. The spreadsheet estimates the DSP activity with respect to three levels of execution: % Signal Processing (SP) Utilization, % Control Code (CC) Utilization, and % Idle Utilization. The sum of these three execution levels cannot exceed 100%, and only % Signal Processing Utilization and % Control Code Utilization are able to be explicitly entered into the spreadsheet.

If the sum of % Signal Processing Utilization and % Control Code Utilization is less than 100%, then the spreadsheet assumes that the remaining percentage is Idle Utilization. The three levels of execution are described in more detail below:

- **% Signal Processing (SP) Utilization** is used to represent scenarios with high levels of DSP activity. This corresponds to the case in which all eight instructions fetched by the DSP are executed in parallel each DSP clock cycle, resulting in all eight functional units being active every cycle. Few DSP algorithms will achieve 100% DSP utilization because this requires execution of all eight function units every cycle with no stalls. Even intense applications do not spend all of the time executing such highly parallel code.
- **% Control Code (CC) Utilization** is used to represent scenarios with low levels of activity. This could embody some type of task-polling loop or background task. The activity for this case represents the execution of approximately two functional units every clock cycle. This type of code typically accounts for 30% of program execution.
- **% Idle Utilization** is used to represent the case in which the DSP is active, but is not doing useful work (NOP execution). This parameter cannot be explicitly entered into the spreadsheet, and is assumed to be the remaining utilization percentage when % Signal Processing Utilization and % Control Code do not sum to 100% (% Idle Utilization = 100% - % Signal Processing Utilization - % Control Code Utilization).

For more information about the DSP architecture, operation, or instruction set, see the *C66x CPU and Instruction Set Reference Guide* (SPRUGH7).

System level issues may also reduce utilization. Although the spreadsheet will accept 100% utilization for all peripherals, this is not possible in reality. As memory and EDMA3 bandwidth is consumed, peripheral activity is throttled back due to these bottlenecks, and, therefore, 100% utilization is not achievable. In applications with a lot of memory and/or EDMA3 usage, individual module utilization numbers should be entered, while keeping this overall limitation in mind.

3.1.2 % Writes

Peripherals that transmit as much as they receive have 50% writes (the spreadsheet will assume the remaining 50% of the time is spent on reads). In some applications, peripherals transmit in only one direction, or have a known balance of data movement. In these cases, the % writes option is not available for configuration. For the peripherals that have the % write configuration, 50% is a typical number that should be used.

3.1.3 % Switching

Random data has a 50% chance that any bit will change from one cycle to the next. Some applications may be able to predict this chance using some *a priori* 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%.

3.2 Peripheral Enabling and Disabling

As mentioned previously, the device includes the capability to disable peripherals to reduce power consumption. This can be done by configuring the Power Sleep Controller. The spreadsheet also allows you to disable peripherals controlled by the PSC to ensure the peripherals' dynamic power is not included in the power calculation if the peripheral is not being used. For more information, see the device-specific data manual and the *Power Sleep Controller (PSC) for KeyStone Devices User Guide* (SPRUGV4).

A peripheral can be enabled or disabled in the spreadsheet from the column labeled *Status*. If a peripheral is disabled, the CVDD and I/O power for the peripheral will be 0. If the peripheral is enabled with 0% utilization, the activity power for CVDD and I/O will be 0. However, the peripheral will have baseline power consumption due to enabling/clocking the peripheral. For more information see the *Power Sleep Controller (PSC) for KeyStone Devices User Guide* (SPRUGV4).

4 Using the Results

The power data presented in this document and the accompanying spreadsheet were collected from devices considered to be at the maximum end of power consumption for production devices. No production units will have average power consumption that exceeds the spreadsheet values. The power consumption estimated by the spreadsheet is the maximum average power consumption. While transient currents may cause power to spike above the spreadsheet values for a small amount of time, over a long period of time, the observed average power consumption will be below the spreadsheet value. Therefore, the spreadsheet values may be used for board thermal analysis and power supply design as a maximum long-term average.

4.1 Adjusting I/O Power Results

I/O power is dependent not only on the DSP and activity, but also on the load being driven. For loads with CMOS inputs, the power required to drive the trace dominates; therefore, the power will scale based on the capacitance loading.

4.2 Spreadsheet Layout and Details

The following sections discuss the spreadsheet layout and details.

4.2.1 Baseline Section of Spreadsheet

The baseline power portion of the results section consolidates the average power associated with leakage, clock tree, and phase-locked loop (PLL) power. The clock tree power includes the power consumed by active clocks within the system.

4.2.2 Activity Section of Spreadsheet

The activity section contains the average power consumption associated with enabling a peripheral along with power consumed due to peripheral activity. The activity levels of a peripheral are defined by the peripheral frequency, % utilization, % writes, % switching, bus width, and peripheral mode.

4.2.3 Totals Section of Spreadsheet

The totals section provides the total in each column for each power supply for Baseline plus Activity power. The total (mW) is equal to the total power for CVDD and I/O, i.e., total device power.

4.3 Current vs. Power Variable Option

There is an option on the spreadsheet that can be used to get the estimates across each of the power rails and the total in terms of Power (in mW) and Current (in mA).

- With the variable set to Power - it uses CVDD= SmartReflex Voltage to provide total power estimates in mW
- With the variable set to Current - it uses CVDD=0.9V to provide total current estimates in mA

This is being done to provide worst case estimates that may be used for board thermal analysis and power supply design as a maximum long-term average.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connctivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated