

TMS320C6411 Power Consumption Summary

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ABSTRACT

This document discusses the power consumption of the Texas Instruments TMS320C6411 digital signal processor (DSP). Power consumption on this device is highly application dependent, so a spreadsheet is provided to model power consumption for a user's application. To get good results from the spreadsheet, realistic usage parameters must be entered. The low core voltage and other power design optimizations allow these DSPs to operate with industry-leading performance, while maintaining a low power-to-performance ratio.

The data presented in this document is actual measured power consumption for the C6411 silicon revision 1.1. Project collateral discussed in this application report can be downloaded from the following URL: <http://www.ti.com/lit/zip/SPRA373>.

Table 1. Typical Activity

Device	Core Voltage	Frequency	Power Per Frequency (mW/MHz) [†]	Power at Frequency (W) [‡]		
			CPU & L1	Internal Logic	IO	Total
C6411	1.2 V	300 MHz	0.4	0.40	0.23	0.63

[†] Assumes 60% CPU utilization

[‡] Assumes 60% CPU utilization, 50% EMIF utilization (75 MHz), 50% writes, 64 bits, 50% bit switching, 2 2MHz MCBSP at 100% utilization, and 2 75MHz Timers at 100% utilization

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1 Activity-Based Models

TMS320C64x power consumption can vary widely depending on the use of on-chip resources. Thus, power consumption can not be estimated accurately without an understanding of the components of the DSP in use and the usage patterns for those components. By providing the usage parameters that describe how and what on the DSP 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, different applications that use the DSP differently can get accurate predictions, all across the spectrum of possible power consumption on the C64x devices.

1.1 Baseline Power

Baseline consumption is power that is consumed that is not dependent on chip activity. This includes things like static power, PLL power, and clock tree power. While independent of activity, baseline power is dependent on voltage and temperature. Thus, the user can affect baseline power only by the selected part (and CVdd voltage) or by the operating temperature.

1.2 Activity Power

Activity consumption is power that is consumed by active parts of the DSP (the CPU, EDMA, peripherals, etc). Active power is independent of temperature, but dependent on voltage and activity levels. Activity power is separated by the major modules of the device, so that their contribution can be measured independently of each other. 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. Module activity power includes necessary EDMA service for peripherals that require it. Note that not all parameters apply to all modules.

- **Frequency** is the operating frequency of a module or the frequency of external interface to that module.
- **% Utilization** is the relative amount of time the module is active or in use versus off or idled.
- **% Write** is the relative amount of time (considering active time only) the module is sending data out of the DSP versus reading data into the DSP.
- **Bits** is the number of data bits being used in a selectable-width interface.
- **% Switch** is the probability that any one data bit will change state from one cycle to the next.

1.3 Modules

The C64x power estimation form contains the following modules with adjustable parameters

- CPU
- EMIF (Includes ECLKOUT1)
 - ECLKOUT2
 - CLKOUT4
 - CLKOUT6

- McBSP 0
- McBSP 1
- Timer 0
- Timer 1
- Timer 2
- HPI
- PCI

EDMA is not listed as a separate module because the module activity models include necessary EDMA service.

2 Using the Power Estimation Spreadsheet

Using the power estimation spreadsheet involves simply entering appropriate usage parameters. Cells that are designed for user input are white in color. To use the spreadsheet, simply:

- Enter the case temperature for which you want to estimate power.
- Fill in the appropriate module use parameters

The spreadsheet will take the provided information and display the details of power consumption for that configuration.

2.1 Choosing Appropriate Values

The frequency and bits user values are determined by design and it will be clear what the correct values to enter are. Modules that are completely unused and unlocked should use 0 for frequency to prevent any idle power from that module from being included. The utilization, read/write balance, and bit switching require estimation and a good understanding of the user application to choose appropriate values.

2.1.1 Utilization

For modules except CPU, 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 IO, utilization can be estimated by comparing used bandwidth with theoretical maximum bandwidth. If, for example, an application must transfer 50 MB/s via the PCI port, with a theoretical 132 MB/s maximum, the PCI port utilization would be about 40%.

The CPU utilization isn't as straightforward, because there are varying degrees of use for the CPU. Here, 0% utilization means the CPU is idle and does no useful work, where 100% utilization means all 8 functional units are active every cycle and the maximum amount of data is brought in from L1P and L1D every cycle. Few DSP algorithms will achieve 100% utilization, because this requires everything to be used every cycle, with no stalls. Even DSP-intense applications do not spend all of the time in such highly parallel loops. Time is typically also spent executing control code or less demanding DSP algorithms. These types of code may execute only a few instructions in parallel and significantly reduce the IO of the CPU, and thus reduce overall utilization. Thus the balance of CPU use for the application must be considered, and entering 100% utilization is not practical for real applications.

For example, an application that executes control code (estimated at 25% of CPU capability) half of the time, and very dense DSP code (estimated at 90% of CPU capability) the other half, would have an average utilization of about 60% ($25\% \times 50\% + 90\% \times 50\%$). If the balance were changed to 25% control code and 75% DSP code, the weighted average would be about 75% utilization ($25\% \times 25\% + 90\% \times 75\%$). If the 25%/75% ratio is kept, but the DSP code does not fully use all the CPU resources (estimate now at 75% of CPU capability) then the overall utilization returns to about 60% ($25\% \times 25\% + 75\% \times 75\%$). Using estimates of intensity and duration of blocks of code in the application, an estimate of the overall CPU utilization can be obtained.

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

2.1.2 % Writes

Peripherals that move data out of the DSP as much as they move data into the DSP have 50% writes. The other 50% of the active time is assumed to be 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% for an application that does only reads, 100% for an application that does only writes, or the known write/read ratio of the application as appropriate. 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 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%

2.2 Power Down Modes

In addition to the power consumption for the supplied parameters, the power calculation spreadsheet gives the power consumption for the CPU power down modes. Note that the PD1 and IDLE power down modes include consumption by idle EMIF.

2.3 Graphs

The graphs page contains graphs that provide a visual breakdown of power consumption. Shown is a comparison of active power (based on the parameters supplied) and the power down modes, and pie charts showing the relative contributions of each module to the core and IO power consumption.

3 Using the Results

The results presented by the spreadsheet are based on measured data for revision 1.1 silicon. The measured units were selected to be at the maximum end of power consumption for production units; no production units will have average power consumption that exceeds the spreadsheet values. The spreadsheet data may therefore be considered maximum average power consumption. That is, transient currents may cause power to spike above the spreadsheet value for a small amount of time, but over a long period of time, the observed average consumption will be below the spreadsheet value. Thus, the spreadsheet value may be used for board thermal analysis and power supply design as a maximum long-term average.

3.1 Adjusting IO Power Results

IO Power is dependent not only on the DSP 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 number of inputs or lumped load capacitance. For the data presented in the spreadsheet, the EMIF, McBSP, and Timer interfaces were loaded with approximately 4 inches of 50 ohm trace, with serial termination. PCI and HPI were loaded with approximately 2.5 inches of 50 ohm trace, with no termination. If the target system has very different IO loading, the spreadsheet results may be scaled either up or down to compensate. For this reason, the spreadsheet allows the user to specify the approximate load on the IO pins for each module. This parameter is used to adjust the reported IO power numbers.

4 Examples

Here are a few examples demonstrating how to choose appropriate values for a particular application. The values used in these examples may be imported into the spreadsheet by clicking the appropriate macro button.

4.1 Image Processor

In this example, the DSP is reading in an image stream of 8 Mbps, performing image transforms and sending the data to an output device. The image is 800x600x16bit @ 10 fps, which is 9600 KB per second. The image data is fed in via EMIF, and 9600 KB of processed data is sent out via EMIF for each frame. A buffer is kept in external memory, which must be written to once and read from 5 times per frame. In addition, a 2 Mbps audio stream is fed into the DSP via McBSP, and 2 Mbps processed audio is sent out via McBSP. The DSP is running at 1.2v, 300 MHz CPU, in a 60C environment. EMIF is running at 75 MHz, with a 32-bit bus and using both ECLKOUTs

- Voltage: 1.2v
- Temp: 60 C
- CPU: 300 MHz, 70% utilization. We estimate CPU utilization based on the following factors:
 - Image Process (very highly optimized DSP algorithm) 90% of CPU capability for 60% of the time.
 - Audio decode (optimized DSP algorithm) 75% of CPU capability for 10% of the time.
 - Background: 10% of CPU capability for 60% of the time

- EMIF: 75 MHz, 25% utilization, 25% writes, 32 bits, 50% switching
 - Acquire: Read 10 MB/s
 - Buffer: Write 10 MB/s, Read 50 MB/s
 - Output: Write 10 MB/s
 - Total: 80 MB/s, 25% of which are writes
- AECLKOUT2: 75 MHz, 100% utilization
- McBSP0: 2 MHz, 100% utilization, 50% switching
- McBSP1: 2 MHz, 100% utilization, 50% switching
- All other modules use 0 MHz, 0% utilization

Entering these values into the spreadsheet gives us a maximum power consumption of about 450 mW core, 190 mW IO, for a total of 650 mW

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