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Estimating Power for ADSP-2156x SHARC+ Processors

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Rev 1 – February 26, 2020

Introduction

This EE-note describes how to estimate power consumption on ADSP-2156x processors, which include a SHARC+[®] high-performance core and a multitude of peripherals, accelerators and high-speed Direct Memory Access (DMA) channels. These processors have multiple power and clock domains. This application note provides a simplified methodology for estimating the total System-on-Chip (SoC) power consumption depending on the amount of processor activity.

Power estimates are based on design simulations and characterization data measured across power supply voltage, core and system clock frequency, and junction temperature (T_j). The power can vary widely depending on how the on-chip ADSP-2156x resources are used. Thus, power consumption cannot be estimated accurately without an understanding of the components in use and the usage patterns for those components. By providing the usage parameters, board designers can obtain accurate consumption estimates to consider when developing power supply and thermal relief solutions for their ADSP-2156x-based products.

See the following sections of the *ADSP-2156x SHARC+ DSP Data Sheet*^[1] for details specific to discussions throughout this EE-Note:

- See the *Recommended Operating Conditions* section for details regarding supported power supply ranges.
- See the *Electrical Characteristics* and subsequent *Total Internal Power Dissipation* sections for details regarding current specifications.

In the *associated file*^[2] furnished with this EE-note, there is a convenient power calculator tool. This tool allows users to obtain a total power profile by populating the cells in a spreadsheet with data found both in the processor data sheet and as a result of calculations specific to the intended application. This document explains the cases where information in the power calculator is not in the data sheet.

This EE-note also describes how to provide the appropriate input to the power calculator such that the full power profile for the application can be obtained. It describes how the calculations are made and how the results contribute to the overall power profile.



Measurements shown in this EE-note and in the power calculator spreadsheet were taken on ADSP-21569 silicon revision 0.0.

Power Domains

There are multiple power domains associated with the ADSP-2156x processor; total power consumption is the sum of the power consumed across all the power domains. There are four major power domains that are significant contributors to the overall power profile:

- V_{DD_INT} : most internal on-chip logic (for example, core, accelerators, DMA engines, and so on)
- V_{DD_EXT} : for example, I/O pad ring, JTAG
- V_{DD_REF} : I/O reference supply
- V_{DD_DMC} : DDR controller

Estimating Internal Power Consumption ($P_{DD_INT_TOT}$)

The total power consumption associated with the on-chip logic (on the V_{DD_INT} supply) is the sum of the static (leakage) and dynamic (switching) power components. The dynamic component depends primarily on processor activity, which includes the instruction execution sequence, the data operands involved, and the instruction rate on each core, as well as the number of active peripherals/accelerators, their clock rates, and any associated DMA data traffic. The dynamic current is also influenced by temperature. The static component is independent of processor activity and is a function of temperature and voltage.

The internal current ($I_{DD_INT_TOT}$) consumed by the ADSP-2156x processors is comprised of:

- $I_{DD_INT_STATIC}$: leakage current
- $I_{DD_INT_CCLK_SHARC0_DYN}$: dynamic current in the CCLK domain for the SHARC+ core
- $I_{DD_INT_DCLK_DYN}$: dynamic current in the DCLK domain (no other activity)
- $I_{DD_INT_SYSCLK_DYN}$: dynamic current in the SYSCLK domain (no other activity)
- $I_{DD_INT_SCLK0_DYN}$: dynamic current in the SCLK0 domain (no other activity)
- $I_{DD_INT_SCLK1_DYN}$: dynamic current in the SCLK1 domain (no other activity)
- $I_{DD_INT_OCLK_DYN}$: dynamic current in the OCLK domain (no other activity)
- $I_{DD_INT_DMA_DR_DYN}$: dynamic current consumed due to DMA activity
- $I_{DD_INT_ACCL_DYN}$: dynamic current consumed by the FIR/IIR accelerator blocks

Therefore, the total current can be expressed as the sum of each of the above components, where there is a single static power component and several dynamic power components that must be included in the overall power profile.

Maximum specifications for I_{DD_INT} are provided in the processor data sheet at specific voltages, frequencies, and temperatures. The following sections describe how to use this data to calculate the overall power requirements of the application.

Estimating Total I_{DD_INT} Dynamic Current

Due to the multi-featured clock and power capabilities of the ADSP-2156x processors, there are many contributors to the overall dynamic component associated with the power consumed by the core. While there is opportunity to disable clocks to the various domains, each must be scrutinized to determine what must be accounted for with respect to power dissipation when any combination of these domains is active in the system.



The dynamic current data included as part of this EE-note and associated power calculator spreadsheet pertains to maximum junction temperature of 125°C and the worst-case (highest-power) fabrication process.

Core Dynamic Current ($I_{DD_INT_CCLK_SHARC_DYN}$)

The ADSP-2156x processor data sheet provides the baseline dynamic current consumption specifications, which are obtained with the processor running what is defined to be a “typical” application. It is represented in the data sheet by the I_{DD_TYP} specification. However, these conditions do not represent all possible application code. Also ignored is the concept of silicon process variation, which influences the power profile because of non-uniform transistor physics across the silicon. When making decisions regarding the power supply design, the worst-case scenario must always be considered. The above assumptions are addressed in two places in the data sheet in order to facilitate extrapolation to obtain the maximum requirements for the power supply design:

- *Dynamic Current* tables – provide the maximum (across process and temperature) core dynamic current specification as a function of voltage (V_{DD_INT}) and frequency (f_{CCLK}) while running “typical” application code
- *Activity Scaling Factor (ASF)* tables – describe discrete dynamic activity levels to provide insight as to how the dynamic current scales with changing loads on the core

Using these combined specifications, the dynamic component of core power consumption can be obtained by multiplying the baseline spec obtained from the *Dynamic Current* tables and the associated ASF, as further explored in the following sections.

SHARC+® Core Activity Scaling Factor (ASF) Vectors

The *Activity Scaling Factors for SHARC+ Core0* table in the data sheet defines the following vectors:

- I_{DD_IDLE} : SHARC+ core executing only the IDLE instruction
- I_{DD_NOP} : SHARC+ core executing 100% NOPs
- $I_{DD_TYP_3070}$: SHARC+ core executing 30% floating-point (FP) multiply/add/subtract and store instructions and 70% NOPs
- $I_{DD_TYP_5050}$: SHARC+ core executing 50% FP multiply/add/subtract and store instructions and 50% NOPs
- $I_{DD_TYP_7030}$: SHARC+ core executing 70% FP multiply/add/subtract and store instructions and 30% NOPs (used for I_{DD_TYP} specification)
- $I_{DD_PEAK_100}$: SHARC+ core executing 100% FP multiply/add/subtract and store instructions
- I_{DD_LS} : SHARC+ core in light sleep mode (*new feature added in ADSP-2156x processors*)



The test code used to measure $I_{DD_PEAK_100}$ represents the worst-case core operation and is not sustainable under normal application conditions.

In addition to the ASFs, the power calculator defines the following vector on the *Core Activity Factors* tab:

- $I_{DD_CLOCK_GATED}$: SHARC+ core clock disabled (no dynamic power)

Using ASFs to Establish Application-Specific Total Average Power Profile

Once the baseline dynamic current specification from the *Dynamic Current* tables is obtained from the spreadsheet cell associated with the CCLK frequency (f_{CCLK}) and the input voltage (V_{DD_INT}) of interest, the

next step is to analyze the application to identify and apply the proper ASFs. The application must be broken down into percentages of time spent in states associated with one of these standard power vectors. With knowledge of the program flow and an estimate of the percentage of time spent at each activity level, the baseline dynamic current and the corresponding ASF can be used to determine the average dynamic current consumption for each core.

For example, $I_{DD_INT_CCLK_SHARC0_DYN}$ for the SHARC+ core0 in a specific application can be calculated according to Equation 1, where “%” is the percentage of the overall time that the application spends in that state:

$$\begin{aligned}
 I_{DD_INT_CCLK_SHARC0_DYN} = & (\% \text{ Peak activity level} \times I_{DD_PEAK_100} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ High activity level} \times I_{DD_TYP_7030} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ Moderate activity level} \times I_{DD_TYP_5050} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ Low activity level} \times I_{DD_TYP_3070} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ NOP activity level} \times I_{DD_NOP} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ IDLE activity level} \times I_{DD_IDLE} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ CCLK disabled} \times I_{DD_CLOCK_GATED} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (\% \text{ LS activity level} \times I_{DD_LS} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN})
 \end{aligned}$$

Equation 1. Total Individual Core Dynamic Current

Note that the $I_{DD_INT_CCLK_SHARC0_DYN}$ output is the average current, whereas the $I_{DD_INT_CCLK_SHARC0_DYN}$ inputs are with ASF = 1.0. Consider a SHARC+ core0 application that is continuously running and never idles, where core activity is:

- $I_{DD_PEAK_100}$ activity level – 10%
- $I_{DD_TYP_7030}$ activity level – 20%
- $I_{DD_TYP_5050}$ activity level – 50%
- $I_{DD_TYP_3070}$ activity level – 10%
- I_{DD_NOP} activity level – 10%
- I_{DD_LS} , I_{DD_DS} , I_{DD_IDLE} and $I_{DD_CLOCK_GATED}$ activity level – 0%

Applying Equation 1 to this profile yields:

$$\begin{aligned}
 I_{DD_INT_CCLK_SHARC0_DYN} = & (0.1 \times I_{DD_PEAK_100} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + (0.2 \times I_{DD_TYP_7030} \text{ ASF} \times \\
 & I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (0.5 \times I_{DD_TYP_5050} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + (0.1 \times I_{DD_TYP_3070} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN}) + \\
 & (0.1 \times I_{DD_NOP} \text{ ASF} \times I_{DD_INT_CCLK_SHARC0_DYN})
 \end{aligned}$$

Estimating System Clock Tree Currents

ADSP-2156x processors have multiple system clock domains to clock the system buses, various peripherals, DMA controllers, L2 memory, and a DDR controller. Each of these clock domains consumes power that dissipates in the internal power domain due to its respective clock toggling inside the chip. Additional power consumed by the peripherals and DMA (when turned on) is attributed to individual peripherals/DMA's running in the system. This power is estimated separately and added to the baseline system power when the total power profile is calculated.

There are four major system clock domains on ADSP-2156x processors: SYSCLK, SCLK0, SCLK1, and DCLK.

There is also a programmable output clock (OCLK), which can be generated by one of the CGUs and routed to an external pin on the processor. It has a small influence on the overall power profile as well.

To estimate the impact to the current consumed in the V_{DD_INT} domain as a result of each of these system clocks, unique scaling factors are furnished in the processor data sheet. The factors represent the currents consumed per MHz per volt in each system clock domain; therefore, V_{DD_INT} is in terms of volts, and f_{XXX} is in terms of MHz in the system clock dynamic current equations:

- $I_{DD_INT_DCLK_DYN} = 0.125 \times V_{DD_INT} \times f_{DCLK}$
- $I_{DD_INT_SYSCLK_DYN} = 0.626 \times V_{DD_INT} \times f_{SYSCLK}$
- $I_{DD_INT_SCLK0_DYN} = 0.23 \times V_{DD_INT} \times f_{SCLK0}$
- $I_{DD_INT_SCLK1_DYN} = 0.02 \times V_{DD_INT} \times f_{SCLK1}$
- $I_{DD_INT_OCLK_DYN} = 0.048 \times V_{DD_INT} \times f_{OCLK}$



The scaling factor for each of the system clock dynamic current equations is in units of mA/MHz/V; therefore, the result for each is in terms of mA.

Estimating DMA Contribution to Internal Dynamic Current ($I_{DD_INT_DMA_DR_DYN}$)

Different types of DMA transactions in the system result in additional power consumption:

- DMA transfers between the various memory spaces
- DMA transfers from memory to peripherals
- DMA transfers from peripherals to memory

Power consumption varies with the number of running DMA channels and the rate at which they move data through the system. To estimate DMA power consumption, three power profiles are available in the power calculator in the *DMA/Peripheral Usage* pull-down in the V_{DD_INT} *Clock Domains & DMA Rates* table on the *Power Estimation* tab:

1. **HIGH:** comprised of high-speed MDMA, multiple low-speed MDMAs, and several high-speed peripheral DMA running simultaneously in the system for a combined throughput of ~5898 MBPS.
2. **MEDIUM:** comprised of medium-speed MDMA, multiple low-speed MDMAs, and several low-speed peripheral DMA running simultaneously in the system for a combined throughput of ~3304 MBPS.
3. **LOW:** comprised of low-speed MDMA and several low-speed peripheral DMA running simultaneously in the system for a combined throughput of ~456 MBPS.

To estimate the DMA dynamic current ($I_{DD_INT_DMA_DR_DYN}$) in the application, the combined data bandwidth of all the DMA running in the system determines which profile to select as the closest match to the actual application and use as the $I_{DD_INT_DMA_DR_DYN}$ component for the $I_{DD_INT_TOT}$ calculation.

High DMA Configuration

The following peripheral and memory DMA are active in this configuration:

- 8 SPORTS @62.5MHz in RX mode with PRI/SEC enabled (writing data to L2)
- 8 SPORTS @62.5MHz in TX mode with PRI/SEC enabled (reading data from L2)

- SPI2/SPI1 in quad mode, SPI0 in dual mode TX operation @62.5MHz (reading data from L2)
- LP TX mode @125MHz (reading data from L2)
- 1x medium speed MDMA transferring data from L1 to L2
- 1x medium speed MDMA transferring data from L2 to L1
- 1x medium speed MDMA transferring data from DDR to L1
- 1x high speed MDMA transferring data from L1 to DDR

In this configuration, the $I_{DD_INT_DMA_DR_DYN}$ component (see the V_{DD_INT} DMA Usage tab of the power calculator) is 240 mA.

Medium DMA Configuration

The following peripheral and memory DMAs are active in this configuration:

- 8 SPORTS @62.5MHz in RX mode with PRI/SEC enabled (writing data to L2)
- 8 SPORTS @62.5MHz in TX mode with PRI/SEC enabled (reading data from L2)
- SPI2/SPI1 in quad mode, SPI0 in dual mode TX operation @62.5MHz (reading data from L2)
- LP TX mode @125MHz (reading data from L2)
- 1x medium speed MDMA transferring data from L1 to L2
- 1x medium speed MDMA transferring data from L2 to L1

In this configuration, the $I_{DD_INT_DMA_DR_DYN}$ component (see the V_{DD_INT} DMA Usage tab of the power calculator) is 150 mA.

Low DMA Configuration

The following peripheral and memory DMAs are active in this configuration:

- 8 SPORTS @62.5MHz in RX mode with PRI/SEC enabled (writing data to L2)
- 8 SPORTS @62.5MHz in TX mode with PRI/SEC enabled (reading data from L2)
- SPI2/SPI1 in quad mode, SPI0 in dual mode TX operation @62.5MHz (reading data from L2)
- LP TX mode @125MHz (reading data from L2)

In this configuration, the $I_{DD_INT_DMA_DR_DYN}$ component (see the V_{DD_INT} DMA Usage tab of the power calculator) is 40 mA.



The $I_{DD_INT_DMA_DR_DYN}$ component value specified for each of the configurations above is the delta between I_{DD_INT} current measurements obtained empirically on the ADSP-2156x EZ-KIT Lite[®] evaluation platform before and after enabling the indicated DMA activity.

Estimating Accelerator Contribution to Internal Dynamic Current ($I_{DD_INT_ACCL_DYN}$)

The high-performance system acceleration engines (FIR and IIR) consume some current in the V_{DD_INT} domain. The total accelerator current is defined as the sum of the current consumed by each of the blocks.

$$I_{DD_INT_ACCL_DYN} = I_{DD_INT_ACCL_FIR_DYN} + I_{DD_INT_ACCL_IIR_DYN}$$

For a typical FIR use case, the $I_{DD_INT_ACCL_FIR_DYN}$ current is ~55mA. For a typical IIR use case, the $I_{DD_INT_ACCL_IIR_DYN}$ current is ~35mA.

Estimating Total Static Current ($I_{DD_INT_STATIC}$)

The static current ($I_{DD_INT_STATIC}$) dissipated across the entire device in the V_{DD_INT} power domain is due to transistor leakage. It is present when power is applied to the power domains, even when all the internal clocks are shut off (by gating/cutting the SYS_CLKIN to the ADSP-2156x processor) and the device is held in reset. As such, static current is solely a function of junction temperature (T_J) and voltage (V_{DD_INT}). Unlike dynamic current, it does not need to be adjusted for discrete core activity levels. $I_{DD_INT_STATIC}$ can be obtained by looking up the value corresponding to the application conditions (such as at a specific V_{DD_INT} and T_J) in the *Static Current* table in the processor data sheet.



The $I_{DD_INT_STATIC}$ specifications in the *Static Current* table in the data sheet are maximum specifications that account for the wafer fabrication process.

Since the static power component is constant for a given voltage and temperature, it is simply added to the total estimated dynamic current when calculating the total power consumption due to the core logic of the processor. When developing power supply and thermal relief designs, ensure that the highest expected junction temperature and voltage is used when extracting data from the *Static Current* table.

Estimating External Power Consumption (P_{DD_EXT} , P_{DD_REF} and P_{DD_DMC})

Total external power consumption ($P_{DD_EXT_TOT}$, dissipated in the V_{DD_EXT} and V_{DD_DMC} power domains) depends on several parameters:

- O – number of output pins associated with the interface
- TR – toggle ratio (percentage of pins that switch any given cycle)
- f – maximum frequency at which the output pins can switch
- V_{DD_EXT} or V_{DD_DMC} – voltage swing of the output pins
- C_L – load capacitance of the output pins
- U – utilization factor (percentage of time that the peripheral is on and running)



In addition to the input capacitance of each device connected to an output, the total capacitance (C_L) must include the capacitance of the processor pin (C_{OUT}), which is driving the load.

The worst-case external pin power scenario occurs when the load capacitor charges and discharges continuously, requiring the pin to toggle each cycle in terms of external supply power, over the maximum V_{DD_EXT} voltage swing (as specified in the data sheet). The maximum switching frequency of a peripheral clock can be considered as f . Since the state of a data pin can change only once per clock cycle, the maximum toggling frequency in that case is $f/2$. When considering the full current profile for the V_{DD_EXT} power domain, there are several peripherals that can contribute to it; each must be considered separately and then summed together to form the single I_{DD_EXT} component of the total estimated power dissipation.

Equation 2 shows how to calculate the average external current (I_{DD_EXT}) using the above parameters:

$$I_{DD_EXT} = O \times f \times V_{DD_EXT} \times C_L \times U \times TR$$

Equation 2. Total External Current (I_{DD_EXT}) Calculation

Estimated average external power consumption (P_{DD_EXT}) can then be calculated as:

$$P_{DD_EXT} = V_{DD_EXT} \times I_{DD_EXT}$$

Substituting from Equation 2, this calculation becomes:

$$P_{DD_EXT} = V_{DD_EXT}^2 \times O \times f \times C_L \times U \times TR$$

Table 1 is an excerpt from the example application use case contained on the V_{DD_EXT} Power Domain tab in the power calculator. It shows the Link Port interface portion to illustrate the concept more clearly.

Peripheral	Frequency in Hz (f)	Number of Output Pins (O)	Pin Capacitance in Farads (C _L)	Toggle Ratio (TR)	Utilization Factor (U)	VDD_REF current per IO (mA)	VDD_EXT (V)	VDD_REF (V)	PDD_EXT (mW)	PDD_REF (mW)	Notes
Link Port - Data pins	6.25E+07	8	3.00E-11	0.25	1.00	0.8	3.30	1.80	40.838	11.520	62.5MHz max frequency cycle, 8-bit data (8 pins @ 0.25 toggle ratio)

Table 1. V_{DD_EXT} Power Consumption Example

As with estimating the I_{DD_EXT} current, the I_{DD_DMC} current consumption for the on-chip DDR3 controller (DMC0) can be estimated depending on the number of pins toggling and the toggle rate. V_{DD_DMC} is used for the voltage swing (obtain the maximum V_{DD_DMC} specification from the data sheet). The V_{DD_DMC} Power Domain tab in the power calculator includes a table like the one referenced by Table 1. The DDR pins are grouped by function (for example, address, data, control, and clock) for the user to customize based on the application.

Estimating I/O Reference Power Consumption (P_{DD_REF})

The I/O reference supply power consumption (P_{DD_REF}) depends on the frequency of I/O switching as depicted in [Table 2](#).

Lower Frequency Limit of I/O Switching (MHz)	Upper Frequency Limit of I/O Switching (MHz)	V_{DD_REF} Current per I/O (mA)
0	32	0.4
32	63	0.8
63	125	1.1

Table 2. V_{DD_REF} current per I/O

The additional contribution for the V_{DD_REF} current is due to the internal oscillator (5 mA) and the OTP (18 mA), which can be taken as it is for calculation purposes.

General Guidelines for Power Supply and Thermal Relief Designs

While estimating average total power associated with a given application, power supply and thermal relief designs must always consider the worst-case scenario in order to prevent operational failures due to the processor being operated out-of-spec as a result of a sagging power rail or an out-of-bounds junction temperature. The following sections provide some advice for supporting this methodology.

Power Supply Sizing

Following recommendations relate to estimating the power supply sizing.

DO:

- Use the maximum expected voltages associated with all the influencing power domains involved in each of the look-up tables and computations discussed throughout this EE-note
- Use the junction temperature associated with the maximum ambient temperature (T_A) that the application is expected to be subjected to for all temperature-related look-ups and computations discussed throughout this EE-note
- Use the highest ASF possible for the application being run
- Calculate power dissipation from each unique voltage domain separately

DO NOT:

- Use typical I_{DD} , nominal voltage, or room temperature specifications
- Use total device power alone

Recommendations for Thermal Relief

Following recommendations can be used when evaluating thermal relief solutions.

DO:

- Use nominal voltages

- Use the junction temperature (T_j) that the processor is expected to be subjected to
- Use the Full-on-Typical (or lower) ASF to match realistic application code activity levels
- Calculate total thermal power for all voltage domains

DO NOT:

- Use typical I_{DD} specifications or room temperature when calculating thermal power
- Use maximum voltage (this is not realistic, as any transient will then exceed the maximum voltage specification)

Example Application Using the Power Calculator

This section provides an example application to illustrate how to use the associated power calculator tool. There are three tabs in the power calculator that contain color-coded cells along with the guidance to populate the yellow cells with the needed system settings. It lets the calculator automatically populate the green cells with either data from other tabs on the spreadsheet or with a calculated result from the user inputs. Some of the yellow cells are free form, whereas others are selectable via a pull-down. The following sections describe what user input is required on each tab to arrive at the overall power dissipation estimation.

Power Estimation Tab

The first tab in the power calculator spreadsheet is the *Power Estimation* tab. This is the main interface for the power calculator, where input is required to properly model the intended system. On this tab, the user must provide all the information regarding the power supplies and intended clock rates throughout the system, as well as the other influences on the overall power dissipation discussed throughout this EE-note (for example, core activity and DMA rates). This tab works in conjunction with the other tabs in the spreadsheet to provide the total power dissipation for the application as a function of all the configurable system-dependent parameters.

The default *Power Estimation* tab is pre-filled with data pertaining to the following conditions. The example application explained further is derived out of this default *Power Estimation* tab.

- Junction temperature at 125°C, to capture data at a worst-case temperature
- SHARC+ core running at 1GHz speed, with all other clocks at their maximum supported speeds
- A typical load profile of 70-30 considered (SHARC0 executes floating-point multiplication, addition, subtraction and store instructions 70% of the time (30% NOPs))
- Both FIR and IIR accelerators in use
- DDR in use. Hence, the variant ADSP-21569 is considered.
- DMA bandwidth considered HIGH
- Link Port, 8x SPORT, 3x SPI considered as peripherals in usage and actively consuming I/O power



Data for any use case/application can be generated easily by modifying the default settings and configurations.

Set the Power Domains and Junction Temperature

The first step is to set the power domains and junction temperature to the maximum levels expected by the application. For example, consider a design that utilizes the following:

- $V_{DD_INT} = 1.0\text{ V}$
- $V_{DD_EXT} = 3.3\text{ V}$
- $V_{DD_REF} = 1.8\text{ V}$
- $V_{DD_DMC} = 1.35\text{ V}$
- $T_J = 125^\circ\text{C}$

The V_{DD_INT} domain and T_J values are used as inputs to look-up tables on other tabs in the power calculator to extract the needed current dissipation data for the calculation. Select the values using the pull-down menus in the *Operating Conditions* table on the *Power Estimation* tab based on the discrete levels defined in the *Static* and *Dynamic Current* tables in the processor data sheet.



The *Static* and *Dynamic Current* tables included in the power calculator are from the referenced processor data sheet. Always verify that the data in the calculator matches what is in the **current** data sheet to ensure that the proper specifications are being included.

Configure the other relevant power domains on the *Power Estimation* tab. Manually input the appropriate values for the V_{DD_EXT} (in the V_{DD_EXT} section), V_{DD_REF} (in the V_{DD_REF} section) and V_{DD_DMC} (in the V_{DD_DMC} section) domains into the relevant yellow cells. The calculator computes the current and/or power in the associated green cells.



There is no error-checking built into the calculator for the range of these power domains. A *Configuration Warning* is associated with each of these yellow cells indicating that the values input must be verified against the processor data sheet.

The V_{DD_EXT} , V_{DD_REF} and V_{DD_DMC} cells are influenced by activity on the V_{DD_EXT} & V_{DD_REF} *Power* and V_{DD_DMC} *Power* tabs, respectively.

Set the Clocks

Input all the clocking information that defines the dynamic currents expected throughout the system. For example, consider a design that utilizes the following:

- $f_{CCLK_SHARC0} = 1000\text{ MHz}$
- $f_{DCLK} = 500\text{ MHz}$
- $f_{SYSCLK} = 500\text{ MHz}$
- $f_{SCLK0} = 125\text{ MHz}$
- $f_{SCLK1} = 250\text{ MHz}$
- $f_{OCLK} = 125\text{ MHz}$

Manually input the values into the corresponding yellow cells in the *Clock Domains & DMA Rates* table. The calculator computes the associated dynamic current in the adjacent green cells.



There is no error-checking built into the calculator for the range of these operating frequencies. A *Configuration Warning* is associated with each of these yellow cells indicating that the values input must be verified against the processor data sheet.

Set the Activity Scaling Factors (ASFs)

As discussed in [Using ASFs to Establish Application-Specific Total Average Power Profile](#), analyze the application to determine the core loads to associate with the application. This step establishes the dynamic power dissipation component for each core, which is handled in the yellow cells in the *CORE0 Average ASF* tables in the V_{DD_INT} section of the *Power Estimation* tab. The proper input for these cells is a fractional number from 0.0 to 1.0 indicating the percentage of time spent by the application at that discrete ASF level. The calculator outputs the *Average ASF* (as described by [Equation 1](#)) in the green cell based on the data on the *Core Activity Factors* tab.



There is no error-checking built into the calculator for the sum of these percentages. A hover message indicating that the “*Sum of these fractions should be 1*” appears, in order to advise the user when inputting data in this section.



The *ASF* tables included in the power calculator are from the referenced processor data sheet. Always verify that the data in the calculator matches what is in the **current** data sheet to ensure that the proper specifications are being included.

A power supply design should use a maximum power dissipation profile accounting for the worst-case scenario. However, to establish an average power profile, the calculator is built to account for all the discrete ASF levels defined by the processor data sheet. The yellow cells can be populated to reflect the actual system model.

For example, after analyzing the application, it is determined that the following describes the core activity levels:

- SHARC+ Core0: 100% typical application (70-30 profile)

When input into the calculator, the corresponding average ASFs are computed as follows:

- $ASF_{SHARC0} = 1.00$

The ASF is then used by the calculator to compute the dynamic current component for the SHARC+ Core0 in the green cells in the *Contribution (mA)* column in the *Clock Domains & DMA Rates* table.

Set the Accelerator Resource Usage

The system accelerator engines (FIR, IIR) dissipate some dynamic power in the V_{DD_INT} domain as part of the total internal dynamic current ($I_{DD_INT_TOT}$) equation in the processor data sheet. This power is accounted for in the V_{DD_INT} section of the *Power Estimation* tab in a series of pull-down yellow cells in the *Resource Usage* table. The selectable mode options for each row provide a look-up value into associated tables on V_{DD_INT} Accelerators in the calculator.

Only the *Typical usage* setting is available, as discussed in [Estimating Accelerator Contribution to Internal Dynamic Current \(\$I_{DD_INT_ACCL_DYN}\$ \)](#).

For example, if the system is using both accelerators: the total contribution would be:

$$I_{DD_INT_ACCL_DYN} = I_{DD_INT_ACCL_FIR_DYN} + I_{DD_INT_ACCL_IIR_DYN} = 55\text{mA} + 35\text{mA} = 90\text{mA}.$$

Select Appropriate DMA Activity Level

The final user input required on the *Power Estimation* tab is the *DMA/Peripheral Usage* row in the *Clock Domains & DMA Rates* table in the V_{DD_INT} section. It is here that the user must select from the three defined profiles discussed in [Estimating DMA Dynamic Current \(\$I_{DD_INT_DMA_DR_DYN}\$ \)](#) (HIGH, MEDIUM, or LOW) as the closest match to the data activity in the system. When selected using the yellow pull-down, the corresponding look-up value from the $I_{DD_INT_DMA_DR_DYN}$ column on the V_{DD_INT} *DMA Usage* tab is populated in the corresponding green cell in the *Contribution (mA)* column.

When considering serial peripherals, along with DDR access and additional MDMA, a HIGH profile is selected (5898 MBPS). The value for DMA contribution is:

$$I_{DD_INT_DMA_DR_DYN} = 240 \text{ mA}$$

V_{DD_EXT} & V_{DD_REF} Power Domain Tab

The V_{DD_EXT} & V_{DD_REF} Power Domain tab is used to calculate the contribution to power from the Link Ports, SPORTs and SPI peripherals.

Calculating V_{DD_EXT} Power

Using the V_{DD_EXT} & V_{DD_REF} Power Domain tab, identify:

- Each V_{DD_EXT} power domain peripheral that is in use in the system, modelling its power profile as a function of how often it is on
- How many pins switch.
- The load capacitance associated with the pins,
- The voltage swing on the pins
- The frequency at which the pins can switch.

As was the case with the *Power Estimation* tab, the yellow cells are those requiring user input, and the green cells are those populated by the calculator.

The V_{DD_EXT} column is automatically populated from the *Power Estimation* tab; the user must fill in all the yellow cells. Consider an application that uses the Link Port, eight serial ports (SPORTs) and three SPIs. For a rough estimation, external frame syncs for SPORTs and low slave selects for SPIs are considered. Most of the columns are easy to populate with the appropriate clock frequencies. However, some frequencies are a function of how the peripheral is configured: the pin capacitance from the design, and the application's use of the peripheral (see [Estimating External Power Consumption \(\$P_{DD_EXT}\$ and \$P_{DD_DMC}\$ \)](#)), the *Number of Output pins* and the *Utilization Factor*.

With the above peripheral configuration information, [Table 3](#) could represent such a system after the user:

- inputs the proper number of output pins (O)
- makes a reasonable guess as to the number of pins switching any given cycle (TR)
- populates the frequency (f) and load capacitance (C_L), and then
- supplies information about the percentage of the time the peripheral is enabled (U)

Peripheral	Frequency in Hz (f)	Number of Output Pins (O)	Pin Capacitance in Farads (C _i)	Toggle Ratio (TR)	Utilization Factor (U)	VDD_REF current per IO (mA)	V _{DD_EXT} (V)	V _{DD_REF} (V)	P _{DD_EXT} (mW)	P _{DD_REF} (mW)	Notes
Link Port - Data pins	6.25E+07	8	3.00E-11	0.25	1.00	0.8	3.30	1.80	40.838	11.520	62.5MHz max frequency cycle, 8-bit data (8 pins @ 0.25 toggle ratio)
Link Port - Clock	1.25E+08	1	3.00E-11	1	1.00	1.1	3.30	1.80	40.838	1.980	125MHz operation
SPORT0-7 -Data pins	3.13E+07	16	3.00E-11	0.25	1.00	0.4	3.30	1.80	40.838	11.520	31.25MHz max frequency cycle, 2 pins per SPORT x 8 (16 pins @ 0.25 toggle ratio)
SPORT0-7 - Clock	6.25E+07	8	3.00E-11	1	1.00	0.8	3.30	1.80	163.350	11.520	62.5MHz operation
SPI2 - Data pins	3.13E+07	4	3.00E-11	0.25	1.00	0.4	3.30	1.80	10.209	2.880	31.25MHz max frequency cycle, Quad mode (4 pins @ 0.25 toggle ratio)
SPI2 - Clock	6.25E+07	1	3.00E-11	1	1.00	0.8	3.30	1.80	20.419	1.440	62.5MHz operation
SPI1 - Data pins	3.13E+07	4	3.00E-11	0.25	1.00	0.4	3.30	1.80	10.209	2.880	31.25MHz max frequency cycle, Quad mode (4 pins @ 0.25 toggle ratio)
SPI1 - Clock	6.25E+07	1	3.00E-11	1	1.00	0.8	3.30	1.80	20.419	1.440	62.5MHz operation
SPI0 - Data pins	3.13E+07	2	3.00E-11	0.25	1.00	0.4	3.30	1.80	5.105	1.440	31.25MHz max frequency cycle, Dual mode (2 pins @ 0.25 toggle ratio)
SPI0 - Clock	6.25E+07	1	3.00E-11	1	1.00	0.8	3.30	1.80	20.419	1.440	62.5MHz operation
Total External Power Dissipation (mW)									372.64		
Total VREF Dissipation (mW)									89.460		

Table 3. Example V_{DD_EXT} Peripheral Usage

The P_{DD_EXT} (mW) column contains the results of the calculator applying Equation 2 to the input data in the other columns. The sum of the power contributions from each of the individual peripheral components is calculated at the bottom of the column. Peripherals can be added or deleted from this profile by inserting or removing rows.

Calculating VDD_REF Power

The V_{DD_REF} power is automatically calculated in the same spreadsheet as V_{DD_EXT} power, since both are related to I/O switching of peripherals. The calculation is done by referring to Table 4 below, for each I/O pin.

Lower Frequency limit of I/O switching (MHz)	Upper Frequency limit of I/O switching (MHz)	VDD_REF current per IO (mA)
0	32	0.4
32	63	0.8
63	125	1.1

Table 4: I/O VREF Current table for P_{DD_REF} calculation

VDD_DMC Power Domain Tab

The V_{DD_DMC} Power Domain tab must be used when using DDR in the application. The concepts from V_{DD_EXT} Power Domain Tab apply to this tab as well. However, the table is slightly different because it is modeling a single interface that has numerous groups of pins that need to be treated differently based on factors that do not remain consistent across the interface. Like the V_{DD_EXT} Power Domain tab, there are green cells that are either populated by the calculator from elsewhere or are the output of a computation. The user must populate the yellow cells with information regarding the configuration of the DDR controller.

As for the green cells on the V_{DD_DMC} Power Domain tab, the power supply information for the V_{DD_DMC} (V) column is automatically extracted from the Power Estimation tab, as is the Frequency in Hz (f) column. Note that the calculator automatically applies the f_{DCLK} rate to the clock (CLK) and Address pins [15:0] rows, as these pins can switch at this rate in a worst-case scenario.

As indicated in Set the Clocks, the DDR clock was configured to be 500 MHz on the Power Estimation tab. Therefore, Table 5 could be an example model for the DDR interface for this application after the pin capacitance and other inputs are finalized by the user.

Peripheral	Frequency in Hz (f)	Number of Output Pins (O)	Pin Capacitance in Farads (C _L)	Toggle Ratio (TR)	Utilization (U)	V _{DDDR} (V)	Pout (mW)	Reasoning	
DDR3L	Address pins [15:0]	2.50E+08	16	5.00E-12	0.25	1.00	1.35	9.11	DCLK_FREQ operation;Worst case execution --> State of pin changes roughly every one fourth max frequency cycle (toggle ratio:0.5)
	Data pins [15:0]	5.00E+08	16	5.00E-12	1	1.00	1.35	72.90	2x DCLK_FREQ operation, Assume DDR configured for write operation;Worst case execution --> State of pin changes twice every clock cycle (toggle ratio:1)
	CTRL	2.50E+08	15	5.00E-12	0.25	1.00	1.35	8.54	DCLK_FREQ/Burst Mode operation,Assume DDR configured for write operation; Worst case execution --> State of pin changes roughly every one fourth max frequency cycle (toggle ratio:0.25)
	CLK	5.00E+08	2	5.00E-12	1	1.00	1.35	9.11	DCLK_FREQ operation;Clk and the differnetial clock signal ;Worst case execution --> State of pin changes twice every clock cycle (toggle ratio:1)

Table 5. Example V_{DD_DMC} Use Case

Because typical DDR accesses are sequential in nature, it is unlikely that the number of address pins toggling any maximum frequency cycle would exceed 25% (four pins). The worst-case model assumes the interface is always running (U = 1.00). For average power dissipation, there could be low-power modes employed, making a fractional *Utilization Factor* possible, which is supported by the calculator.

Summarizing the Process of Estimating Power

Use the following steps as an example to estimate total overall power in an ADSP-2156x processor design.

Step 1: Obtain the Internal Static Current Component (I_{DD_INT_STATIC})

Use the maximum power rail (V_{DD_INT}) and junction temperature (T_J) values for the application to look up the appropriate maximum I_{DD_INT_STATIC} specification from the *Static Current* table in the processor data sheet. In the example discussed in [Set the Power Domains and Junction Temperature](#), V_{DD_INT} = 1.0 V and T_J = 125 °C; therefore, the associated value from the *V_{DD_INT} Maximum Static Current* tab is 761.98 mA.

Step 2: Obtain Baseline Core Dynamic Currents (I_{DD_INT_CCLK_SHARC0_DYN})

Use the same V_{DD_INT} power rail and the expected core clock frequency (f_{CCLK}) to look up the appropriate values in the *Dynamic Current* tables in the processor data sheet for each core. In the example discussed in [Set the Clocks](#), V_{DD_INT} = 1.0 V and the core is running at 1000 MHz; therefore, the associated values from the equations in [Core Dynamic Current](#) (also in the *Dynamic Current* data sheet tables) are:

- $I_{DD_INT_CCLK_SHARC0_DYN} = 0.713 \times V_{DD_INT} \times f_{CCLK_SHARC0} \rightarrow 0.713 \times 1.0 \times 1000 = 713 \text{ mA}$

Step 3: Model Application to Establish Activity Scale Factors (ASF_{SHARC0})

Using the definitions of the scale factors in the *Activity Scaling Factors* tables in the data sheet, model the application for each core to determine the processor load as a result of the code being executed. For a maximum calculation, use the worst-case ASF at any given time. Calculate an average ASF, as described in the [Using ASFs](#) section. From the example provided in [Set the Activity Scaling Factors \(ASFs\)](#):

- $ASF_{SHARC0} = 1.00$

Step 4: Apply ASFs to Core Dynamic Components

Apply the calculated average ASF or the worst-case ASF to the core dynamic component for each core as a simple multiplication:

- $I_{DD_INT_CCLK_SHARC0_DYN} = I_{DD_INT_CCLK_SHARC0_DYN} \times ASF_{SHARC0} \rightarrow 713 \times 1.00 = 713 \text{ mA}$

Step 5: Calculate the System Clock Tree Core Dynamic Currents

The dynamic current dissipated in the V_{DD_INT} domain as a result of the clocks toggling inside the processor are a function of the internal voltage (in Volts) and the frequency of each clock (in MHz), as governed by the equations in the processor data sheet. Using the example from [Estimating System Clock Tree Currents](#):

- $I_{DD_INT_DCLK_DYN} = 0.125 \times f_{DCLK} \times V_{DD_INT} \rightarrow 0.125 \times 500 \times 1.0 = 62.50 \text{ mA}$
- $I_{DD_INT_SYSCLK_DYN} = 0.626 \times f_{SYSCLK} \times V_{DD_INT} \rightarrow 0.626 \times 500 \times 1.0 = 313.00 \text{ mA}$
- $I_{DD_INT_SCLK0_DYN} = 0.23 \times f_{SCLK0} \times V_{DD_INT} \rightarrow 0.23 \times 125 \times 1.0 = 28.75 \text{ mA}$
- $I_{DD_INT_SCLK1_DYN} = 0.02 \times f_{SCLK1} \times V_{DD_INT} \rightarrow 0.02 \times 250 \times 1.0 = 5.00 \text{ mA}$
- $I_{DD_INT_OCLK_DYN} = 0.048 \times f_{OCLK} \times V_{DD_INT} \rightarrow 0.048 \times 125 \times 1.0 = 6.00 \text{ mA}$

Step 6: Choose a DMA Profile to Obtain Core Dynamic DMA Current ($I_{DD_INT_DMA_DR_DYN}$)

Calculate the total system DMA bandwidth during peak activity and select the profile that is the closest match. The example in [Select Appropriate DMA Activity Level](#) sets the DMA profile to HIGH, therefore:

- $I_{DD_INT_DMA_DR_DYN} = 240 \text{ mA}$

Step 7: Account for Core Dynamic Currents from Accelerator Blocks ($I_{DD_INT_ACCL_DYN}$)

Each of these blocks dissipates power in the V_{DD_INT} domain and must be considered when estimating the total core dynamic current. The example discussed in [Set the Peripheral Resource Usage](#) has the system acceleration engine enabled, therefore:

- $I_{DD_INT_ACCL_DYN} = 90 \text{ mA}$

Step 8: Calculate Total Internal Power Dissipation ($P_{DD_INT_TOT}$)

Add the static internal current ([Step 1](#)) component to the sum of all the dynamic internal current components ([Step 4](#) through [Step 7](#)) to get the total current in the V_{DD_INT} domain ($I_{DD_INT_TOT}$):

$$I_{DD_INT_TOT} = I_{DD_INT_STATIC} + I_{DD_INT_CCLK_SHARC0_DYN} + I_{DD_INT_DCLK_DYN} + I_{DD_INT_SYSCLK_DYN} + I_{DD_INT_SCLK0_DYN} + I_{DD_INT_SCLK1_DYN} + I_{DD_INT_OCLK_DYN} + I_{DD_INT_ACCL_DYN} + I_{DD_INT_DMA_DR_DYN}$$

$$I_{DD_INT_TOT} = 761.98 + 713.00 + 62.50 + 313.00 + 28.75 + 5.00 + 6.00 + 90.00 + 240 = 2220.23 \text{ mA}$$

With the total $I_{DD_INT_TOT}$ current calculated, estimate the total power ($P_{DD_INT_TOT}$):

- $P_{DD_INT_TOT} = I_{DD_INT_TOT} \times V_{DD_INT} \rightarrow 2224.36 \text{ mA} \times 1.0 \text{ V} = 2220.23 \text{ mW}$

Step 9: Calculate External Power Dissipation ($P_{DD_EXT_TOT}$)

The total external power dissipation ($P_{DD_EXT_TOT}$) is comprised of the power dissipated in each of the two critical power domains (V_{DD_EXT} , V_{DD_DMC}) as well as from V_{DD_REF} domain.

Calculate Power Dissipated in the V_{DD_EXT} and V_{DD_REF} Domain (P_{DD_EXT} & P_{DD_REF})

Model the application using the concepts discussed in [Estimating External Power Consumption](#) (P_{DD_EXT} , P_{DD_REF} and P_{DD_DMC}) to estimate the power dissipated in the V_{DD_EXT} domain (P_{DD_EXT}) and V_{DD_REF} domain (P_{DD_REF}). From the example discussed in [V_{DD_EXT} & V_{DD_REF} Power Domain Tab](#):

- $P_{DD_EXT} = 372.64 \text{ mW}$
- $P_{DD_REF} = 89.460 \text{ mW}$

Calculate Power Dissipated in the V_{DD_DMC} Domain (P_{DD_DMC})

Model the application using the concepts discussed in [Estimating External Power Consumption \(\$P_{DD_EXT}\$ and \$P_{DD_DMC}\$ \)](#) to estimate the power dissipated in the V_{DD_DMC} domain (P_{DD_DMC}). From the example discussed in [V_{DD_DMC} Power Domain Tab](#):

- $P_{DD_DMC} = 99.67\text{mW}$

Step 10: Calculate Total Power Dissipation (P_{DD_TOT})

Finally, with all of the core and system elements properly modelled, calculate the total power dissipation as the sum of the internal ($P_{DD_INT_TOT}$) and external ($P_{DD_EXT_TOT}$) power dissipation components:

$$P_{DD_EXT_TOT} = P_{DD_EXT} + P_{DD_REF} + P_{DD_DMC}$$

- $P_{DD_TOT} = P_{DD_INT_TOT} + P_{DD_EXT_TOT} \rightarrow 2220.23 + 372.64 + 89.46 + 99.67 = 2782\text{mW} = \sim 2.782\text{W}$



Due to rounding in the calculations in the example, the values output in the green cells of the power calculator may differ slightly from those presented.

References

- [1] *ADSP-2156x SHARC+ Single Core High Performance Data Sheet (up to 1 GHz). Rev. PrE, September 2019.* Analog Devices, Inc.
- [2] *ADSP-2156x SHARC+ Processor Hardware Reference. Revision 0.2, September 2019.* Analog Devices, Inc.
- [3] *SHARC+ Core Programming Reference. Rev. 1.2, August 2019.* Analog Devices, Inc.
- [4] *EE-392: Estimating Power for ADSP-SC58x/2158x SHARC+ Processors. Rev. 1, October 2016.* Analog Devices, Inc.

Document History

Revision	Description
<i>Rev 1 – February 2020 by Prasanth Rajagopal</i>	<i>Initial Release.</i>