Application Report

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Power Estimation and Power Consumption Summary for TMS320C5504/05/14/15/32/33/34/35/45 Devices

ABSTRACT

This application report assists in estimating the power consumption for the TMS320C5515, C5504, C5505, C5514, C5532, C5533, C5534, C5535 and C5545 devices (DSPs), using a power estimation spreadsheet.

The spreadsheet discussed in this document can be downloaded from the following URL: http://www.ti.com/lit/zip/sprabn0.

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1 Introduction

Power consumption on these devices is highly application-dependent, therefore, a spreadsheet is provided to estimate power consumption. The power spreadsheet allows entering parameters that closely resemble the application to generate a realistic estimate of DSP power consumption based on the input. It also allows the ability to test the efficiency of different configurations before assembling hardware or writing code.

To obtain good results from the power spreadsheet, realistic usage parameters must be entered. 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.

Table 1 is the power consumption summary gathered from the power spreadsheet. The data in the power spreadsheet is an estimate based on measuring units from the high end of the expected power consumption spectrum.

Table 1. Power Consumption Summary

CVDD (V)	DVDDIO (V)	CRTC (V)	Configuration	CPU Frequency (MHz)	Total Power (mW)
0	0	1.3	RTC power only	0	0.2
1.05	1.8	1.05	Standby power	0.032	0.7
1.05	1.8	1.05	Voice encoder	40	10.3
1.05	3.3	1.05	Typical - 60 MHz	60	16.7
1.3	3.3	1.3	Typical - 100 MHz	100	51.9
1.4	3.3	1.3	Typical - 150 MHz	150	149.9

The power data presented in Table 1 is measured under the following condition:

Room Temp (25 °C), 75% DMAC + 25% ADD (typical sine wave data switching)

I/O pins are properly terminated.

Also, the actual current draw varies across manufacturing processes and is highly application-dependent. Table 1 is a power consumption summary considering few of the typical scenarios; for estimating power with other temperature and enabling or disabling peripherals use the power estimation spread sheet.

2 Activity-Based Models

Power consumption is application-dependent on the TMS320C5504/C5505/C5514/C5515/C5532/C5533/C5534/C5535/45 devices. Therefore, the power consumption for a particular application depends on the level of CPU and peripheral activity models. A clear understanding of the CPU, peripherals, and I/O activity levels of the application is recommended to get a realistic result. The output of the power estimation spreadsheet can aid in power supply design or battery life prediction. The model used in this spreadsheet is based on two modes of power consumption: static and active power. With this approach, each of the DSP components (CPU, peripherals, and I/O pins) can be isolated to determine how it contributes to the overall power consumption.

2.1 Static Power

Static power is what is consumed when the on-chip oscillator is shut down (the clock generation domain is idle). If an external clock source is used instead of the on-chip oscillator, the static power is consumed when the external clock source is stopped; therefore, no activity on the DSP is being clocked. The static power consumption depends purely on the core, I/O voltages, and the device operating temperature.

2.2 Active Power

Active power is what is consumed by the active parts of the DSP. These include the CPU, peripherals, and I/O pins associated with the peripherals. The active power consumption is based on the supply voltages, operating frequency, and how each peripheral is configured. To get a better understanding of the distribution of the active power consumption, each module can be evaluated independently.

3 Modules

Each of the following modules and sub-modules can be configured in the power estimation spreadsheet, within realistic operating parameters.

- Phase-Locked Loop (PLL)
- Central Processing Unit (CPU) and CLKOUT
- External Memory Interface (EMIF)
- Liquid Crystal Display Controller (LCDC)
- Direct Memory Access (DMA) (Up to 4 channels)
- Inter-IC Sound (I2S) (Up to 4 channels)
- Multimedia Card/Secure Digital (MMC/SD) (Up to 2 channels)
- Serial Port Interface (SPI)
- Universal Asynchronous Receiver/Transmitter (UART)
- Inter-Integrated Circuit (I2C)
- General-Purpose Timer (Up to 3 timers)
- Real-Time Clock (RTC) and RTC CLKOUT
- General-Purpose Input/External Flag Output (GPIO/XF)
- Successive Approximation (SAR) Analog-to-Digital Converter (ADC)

NOTE: EMIF is not supported in the C5532/33/34/35/45 devices.

The parameters used to describe each module activity are:

- Frequency is the operating frequency of a module, or it is the operating frequency of the interface to that module.
- Idle Status indicates whether the module is in idle or in active state.
- %Utilization is the percentage of activity in a module relative to its maximum.

Every module may not include all of these parameters.

4 Using the Power Estimation Spreadsheet

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

1. Select the voltage, PLLs configuration, and device frequency for the estimated end application.
2. Fill in the appropriate module use parameters.

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

As the spreadsheet is configured, not all settings are checked for conflicts; for example, peripheral clock frequency out of allowed range. For maximum frequency limitations, see the device-specific data manual. For best results, enter the information from left to right, starting at the top and moving downward.

Although the spreadsheet is developed for the C5515 device, it can be used to model power consumption on the C5504, C5505, C5514, C5532, C5533, C5534, C5535 and C5545 devices. Features not supported on these devices should not be enabled in the spreadsheet.

4.1 Choosing Appropriate Values

The accuracy of the results produced by the power estimation spreadsheet depends on how closely the entered parameters match with those of the actual system. Each module must be considered separately for a given process and must account for all activity included in a given operation. For instance, EMIF activity is not included in the CPU activity when the code is executed from external memory. The EMIF activity must be included separately in the *EMIF* section of the spreadsheet.

4.2 Frequency

In some cases, the frequency parameter for a particular module denotes the output frequency of that module. For others, it denotes the internal operating frequency of the module.

4.2.1 PLL

The PLL frequency is the output frequency of the clock generator in the PLL-lock mode. The PLL synthesized is distributed to the CPU and the peripheral. Some of the internal logic of the peripheral runs at the same rate as the CPU. Other peripherals support a user-configurable pre-scaler to run the module at an integer fraction of the CPU clock. For example, the internal logic of the DMA runs at the same rate as the CPU, but the I2C modules can be programmed to run its internal logic (state machine) at a much slower speed. The clock frequency of the PLL and module clocks should not be set in a manner that violates the frequency restrictions imposed by the device data sheet and module reference guide. The PLL operation frequency ranges between 60 and 150 MHz. An external clock is required to support over 120 MHz.

4.2.2 CPU and CLKOUT

The clock frequency of the CPU can be set to the same frequency of the PLL output or divided clock frequency. The CLKOUT frequency is programmable, and should be set as in range specified by the spec.

The CPU operation range is:

- 0–50/60/75 MHz at 1.05-V CVDD
- 0–100/120 MHz at 1.3-V CVDD
- 120-150 MHz at 1.4-V CVDD

4.2.3 EMIF

The frequency field represents the EMIF CLKMEM frequency. External clocking of the EMIF is not supported.

EMIF operation frequency is:

- 0–100 MHz if the CPU is under 100 MHz
- If the CPU is over 100 MHz, then EMIF should run at half of the CPU frequency.

NOTE: EMIF is not supported in the C5532/33/34/35/45 devices.

4.2.4 GPIO and XF

The frequency input for GPIO and XF indicate the frequency at which the states of the GPIO pins are updated. The maximum output frequency of GPIO is 1/6 CPU frequency.

NOTE: XF function is not supported in C5545 device.

4.3 CPU Operating Conditions (Typical)

Table 2. CPU Operating Conditions

CPU Operating Frequency	Supply Voltage (Typical)
60 MHz	1.05 V
75 MHz	1.05 V
100 MHz	1.3 V

4.4 Percentage Utilization

Utilization is explicitly defined for each module, to provide a more accurate estimate of power consumption. If a module is not listed, it is assumed to be in use whenever it is not idle, or, in some cases, like RTC and WDT, the contribution of the modules, while active and being maximally utilized, is small enough to be neglected as compared to the total current consumed.

Table 3. Module Percentage Utilization

Module	Utilization Details
CPU	Because the CPU can be involved in a wide range of activities, it is difficult to provide an exact CPU utilization number. Whenever the CPU is active (non-idle), it is executing some type of instruction; for this reason, 0% activity is assumed as a CPU executing the smallest amount of power the CPU can consume while active. Conversely, 100% activity is assumed as the most power-intensive instruction—the dual multiply and accumulate. All other instructions fall somewhere in between. No single algorithm will achieve 100% utilization, but some highly optimized functions can come close. On the other hand, when the CPU performs control-oriented tasks, it consumes far less current. Assume, for example, that a certain application executes control code half of the time and a highly optimized algorithm for the other half. If the control code is estimated to be at 30% utilization, and the dense DSP code is estimated to be at 90% utilization, the overall utilization will be 60% (30% × 50% + 90% × 50%). If the application spent more time executing the optimized algorithm, utilization would go up, and vice versa. Examining individual segments of an application and estimating the time spent and the CPU utilization in each segment can provide a more accurate percentage of the CPU utilization.
EMIF	EMIF utilization is related to the maximum bandwidth of the EMIF. 100% utilization corresponds to the maximum transfer rate for a given frequency when doing these types of transfers. This number is scaled down by both slower and less frequent transfers. In case of SDRAM, for writes, 100% utilization or maximum throughput is one 16-bit word/cycle (with write posting enabled). (EMIF is configured to communicate with the SDRAM using the divide-by-1 clock mode, that is, CLKMEM equals the CPU clock frequency.) The utilization percentage is defined as the throughput of the application under question, divided by the maximum throughput rates as defined above. For example, CPU reading data from SDRAM at the rate of a 16-bit word every 20 cycles yields 20% EMIF utilization **Note:** EMIF is not supported in the C5532/33/34/35/45 devices.
DMA	DMA utilization for a given channel is based on the maximum attainable data transfer rate between the SARAM and DARAM port, which is one 32-bit transfer per CPU cycle. Twenty-percent DMA channel utilization would yield one 32-bit transfer per five CPU cycles.
I2S	I2S utilization is defined as the percentage of time that the I2S is transferring data. The rest of the time the I2S is assumed to be not transferring any data.
MMCSD	MMCSD utilization is defined as the percentage of time that the MMCSD is transferring data. The rest of the time the MMCSD is assumed to be not transferring any data.
SPI	SPI utilization is defined as the percentage of time that the SPI is transferring data. The rest of the time the SPI is assumed to be not transferring any data.
UART	UART utilization is defined as the percentage of time that the UART is transferring data. The rest of the time the UART is assumed to be not transferring any data.
I2C	I2C utilization is defined as the percentage of time that the I2C is transferring data. The rest of the time the I2C is assumed to be not transferring any data.
TIMER	Timer utilization is defined as the percentage of time that the timer is counting.
USB	USB utilization is based on the maximum attainable data transfer rate between the DSP memory and the USB host device.
GPIO/ XF	Utilization for general-purpose outputs is the percentage of time that they are switching at their specified frequency.
SAR	SAR utilization is defined as the percentage of time that the SAR is performing the analog-to-digital conversion.

4.5 Other Parameters

Some modules, outlined in the following sections, have additional parameters for a more granular estimation of the power consumption.

- MMC/SD – This value lists the total number of MMC/SD instances consuming active power.
- Timer – This value lists the total number of Timer instances consuming active power.
- GPIO/XF – This value lists the total number of GPIO pins consuming active power.

4.6 Power Units

The results are estimated in the spreadsheet and displayed in milliamps (mA) or milliwatts (mW). Click the units in the total row of the calculated results and use the drop-down menu to select the desired units.

4.7 Peripheral Enabling, Disabling, and Shut Off

As mentioned previously, the C5515 device provides the capability to disable modules that are not being used through the clock gating. 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 where a peripheral can be specified as disable or enabled.

- If a module is not used for a given application, then it is recommended to keep it in a disabled state.
- The module can be kept enabled with no activity. To achieve this, program the % utilization or the frequency fields to a value of 0 to get the numbers in the module row indicative of the power consumed by clocking the module.
- A peripheral can be shut off if the peripheral is never used in the design, or not supported (EMIF in-case of C5532/33/34/35/45).

4.8 Using the Results

The results presented in the spreadsheet are based on measured data using the C5515 device. Most production units, if correctly used, typically consume power around the value given in the spreadsheet. Transient currents can cause power to spike above the estimated value for short periods, but long-term power consumption should be similar to the spreadsheet value. This allows for better estimates of power supply requirements, and more accurate battery life predictions.

4.9 Example

NOTE: Before using the spreadsheet, open it and verify that macros are enabled.

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

The RTC Only macro button reports the power consumed with 1.3 V applied to RTC CVDD, 3.3 V volts to DVDDRTC and 1.8 V to LDOI. Other rails are powered off.

The Standby (IDLE3) macro button reports the power consumed with the RTCCLOCK. PLL is powered down and disabled and the system is operating in PLL bypass mode with the RTCCLOCK as the system clock. CPU is in IDLE state which it is in active. All peripherals are disabled except EMIF and USB are shut off.

The Voice Encoder macro button reports the power consumed on the voice encoder. PLL sets to 80 MHz and CPU runs at 40 MHz. One DMA controller is on and patches audio sample data from one active I2S port. CPU is utilized about 88% doing voice encoding. Audio sampling rate is 16 KHz.

The Typical-60 MHz macro button can be used to quickly visualize the use case scenario. The details of the peripherals and their operating conditions used in this scenario are for the voice encoder:

- Core Voltage: 1.05 V
- ANA Voltage: 1.3 V
- PLL Voltage: 1.3 V
- DVDDIO Voltage: 3.3 V
- LDOI Voltage: 3.3 V
- PLL input clock: 32.768 KHz
- CPU Frequency: 60 MHz
- CPU: Enabled, 70% Utilization
- I2S: Enabled and running at 1.5 MHz, 100% Utilization
- DMA: Enabled and 2% Utilization
- UART: Enabled and running at 3 MHz, 50% Utilization
- I2C: Enabled, 400 KHz, 10% Utilization

All other modules are not used and disabled. EMIF and USB are shut off.

The Typical 100 MHz macro button is similar to the Typical 60 MHz macro button, except that core voltage is at 1.3 V, EMIF-enabled, and the device is running at 100 MHz.

4.10 Limitations

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

- Currently six macros are shown to demonstrate power consumption summary for various supported frequencies. But based on the user application, one can edit and fill in the right parameters to get realistic power consumption data.
- The device uses pin multiplexing to accommodate a larger number of peripheral functions in the smallest possible package, providing the ultimate flexibility for end applications. Choose the correct peripheral function, considering the end application aligned with pin-muxing configuration. The power spreadsheet does not highlight warnings or errors, if the wrong pin-mux configuration is chosen.

5 C55xx Comparison

5.1 Feature Comparison Chart – C551x and C553x Devices

Table 4 illustrates the feature comparison of C55xx devices.

Table 4. Feature Comparison Chart

	C551x/3x Feature Support Comparison Chart		
	C5515	C5535	C5545
EMIF	√		
LCDC	√	√	√
DMA	√	√	√
I2S 0	√	√	√
I2S 1	√	√	√
I2S 2	√	√	√
I2S 3	√	√	√
MMCSD	√	√	√
SPI	√	√	√
UART	√	√	√
I2C	√	√	√
TIMER	√	√	√
ISB	√	√	√
GPIO	√	√	√
SAR	√	√	√
XF	√	√	
McSPI			
McBSP			
HPI			

6 Downloads

The TMS320C5504/05/14/15/32/33/34/35/45 power spreadsheet discussed in this document can be downloaded from: http://www.ti.com/lit/zip/sprabn0.

7 References

- *TMS320C5515 Fixed-Point Digital Signal Processor* (SPRS645)
- *TMS320C5535, 'C5534, 'C5533, 'C5532 Fixed-Point Digital Signal Processors* (SPRS737)
- *TMS320C5545 Fixed-Point Digital Signal Processor Data Manual* (SPRS853)

Power Estimation Illustration Using Power Spreadsheet Snapshots

A.1 Idle3 Power Calculation

Table 5 provides the power calculation summary of IDLE3 power with respect to core voltages.

Table 5. Idle3 Power Calculation

	CVDD - 1.05 V	CVDD - 1.3 V
DVDD IO at 1.8 V		
Idle3 mode	0.726 mW	0.875 mW
DVDD IO at 3.3 V		
Idle3 mode	1.709 mW	1.858 mW

Figure 1 illustrates the IDLE3 power calculation using the power spreadsheet.

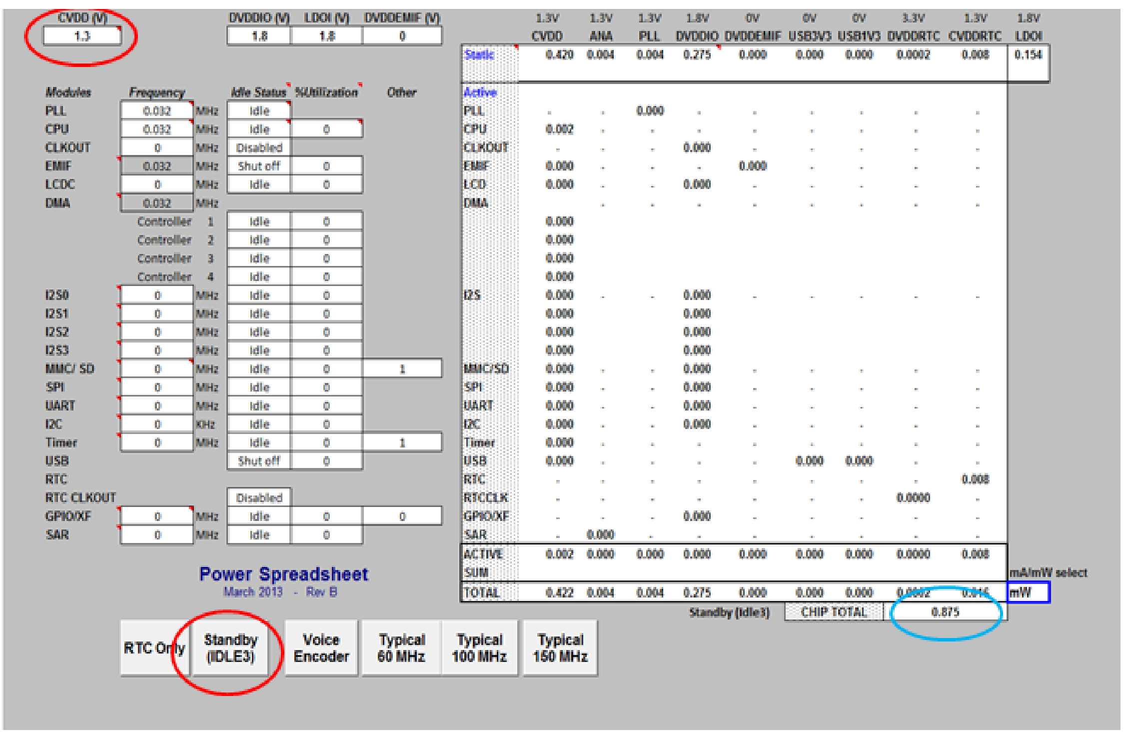

Figure 1. IDLE3 Power Snapshot

A.2 Typical Power Comparison Chart for Frequencies – 60 MHz, 75 MHz, 100 MHz

Table 6 presents the power comparison chart for frequencies: 60 MHz, 75 MHz, 100 MHz, and 150 MHz, with EMIF in both active and shutdown state.

Table 6. Power Comparison Chart at Various Frequencies

Frequencies	C5515 - Power (mW)	C5532/33/34/35/45 - Power (mW)
60 MHz	16.701 (EMIF Shutoff)	16.701
60 MHz	18.627 (EMIF Active)	NA
75 MHz	22.187	19.87
100 MHz	51.883	35.425
150 MHz	149.907	NA

A.2.1 Typical 60-MHz Power Calculation for C5515 Device (with EMIF active)

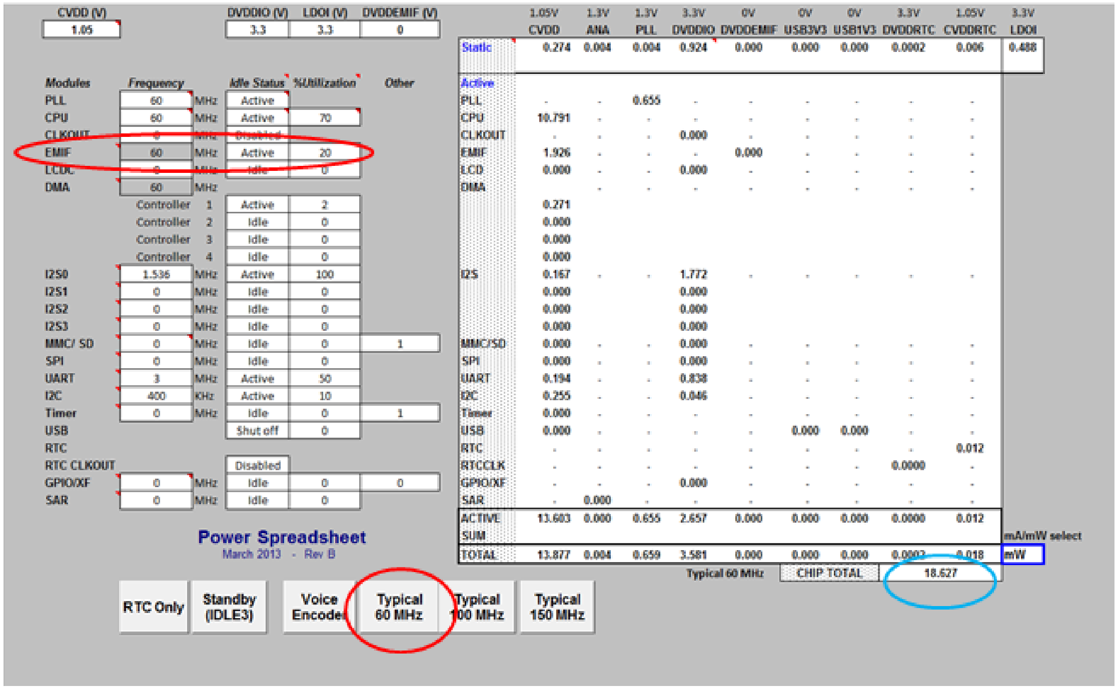

Figure 2. 60-MHz Power Calculation (with EMIF active)

A.2.2 Typical 100-MHz Power Calculation for C5515

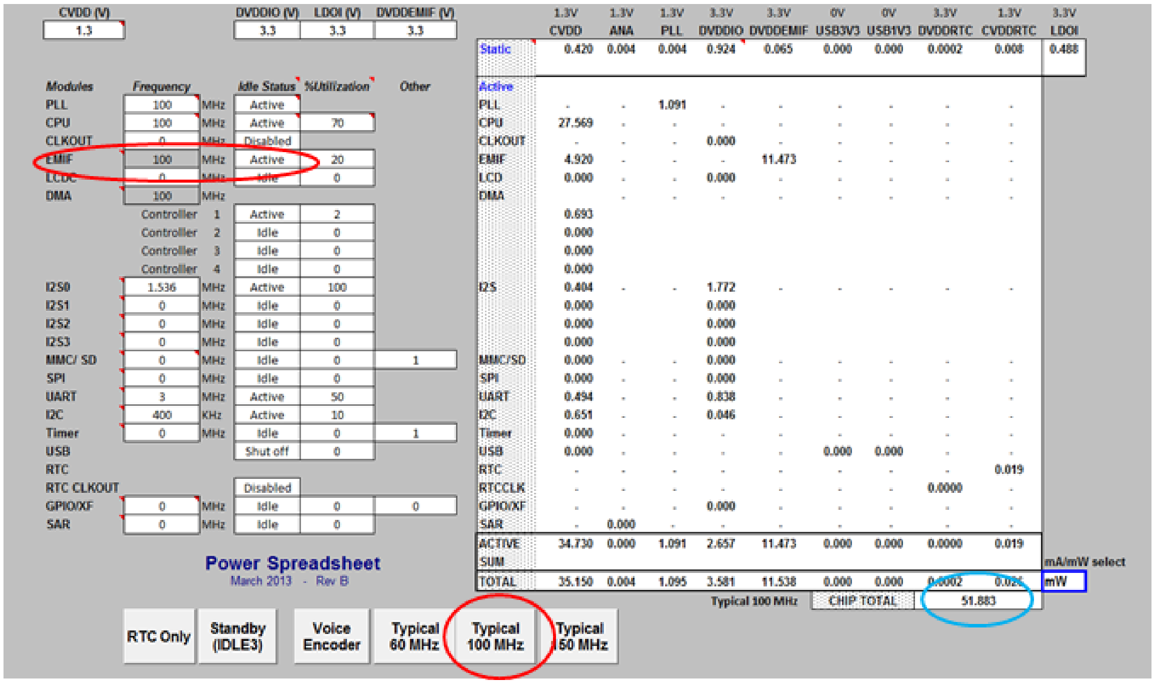

Figure 3. 100-MHz Power Calculation (with EMIF)

A.2.3 Typical 100-MHz Power Calculation for the C5532/33/34/35/45Devices (with no EMIF module)

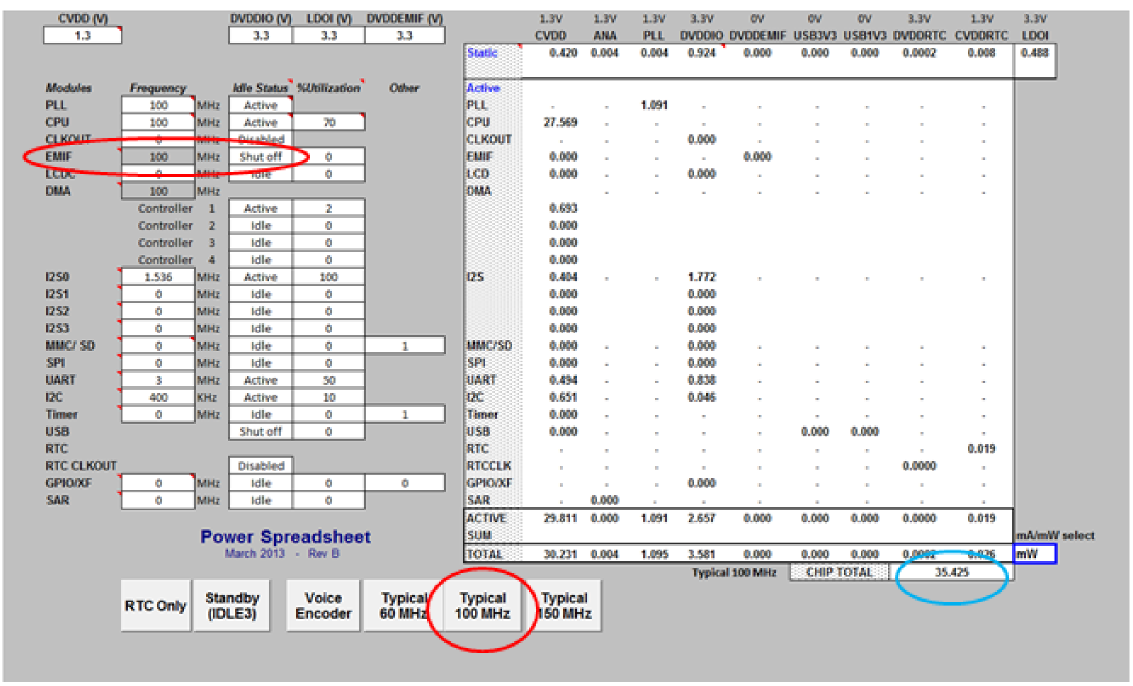

Figure 4. 100-MHz Power Calculation (with no EMIF)

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (October 2015) to A Revision	Page
• Updated the document to include the TMS320C5545 device.	1

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