Power and Thermal Design Considerations Using TI's AM57x Processor

Design Overview
This TI Design (TIDEP0047) is a reference platform based on the AM57x processor and companion TPS659037 power management integrated circuit (PMIC). This TI Design specifically highlights important power and thermal design considerations and techniques for systems designed with AM57x and TPS659037. Included in this design is reference material and documentation covering power management design, power distribution network (PDN) design considerations, thermal design considerations, estimating power consumption, and a power consumption summary.

Design Resources
- TIDEP0047: Tool Folder Containing Design Files
- AM5728: Product Folder
- AM5726: Product Folder
- AM5718: Product Folder
- AM5716: Product Folder
- TMDSEVMAM572X: EVM Tool Folder
- Processor SDK: Download Software

Design Features
- AM57x Processor With Dual ARM® Cortex®-A15, C66x DSP, ARM Cortex-M4, SGX544 Graphics, and Quad Core PRU-ICSS Feature Set
- TPS659037 Companion PMIC
- Design Reference for PMIC, PDN, and Thermal
- Power Estimation Tool (PET) for Estimating System Power and Power Consumption Summary
- Tested, and Includes a Hardware Reference (EVM), Schematics, Design Files, Bill of Materials, Design Guide, and Links to Several Application Notes Containing Design Material

Featured Applications
- Industrial Automation
- Human Machine Interface
- Medical Imaging
- Patient Monitoring
- Aviation Control
- Machine Vision
- Test and Measurement
- Digital Signage
- Industrial PC

An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

Sitara is a trademark of Texas Instruments.
ARM, Cortex are registered trademarks of ARM.

TIDUA2A—October 2015—Revised July 2016
Submit Documentation Feedback

Copyright © 2015–2016, Texas Instruments Incorporated
1 Introduction

This TI Design highlights important power and thermal design considerations and techniques for systems designed with AM57x and TPS659037. This reference design is based on the AM57x EVM. Included is a complete set of schematics, BOM, and board design files. Reference material and documentation covering power management design, power distribution network (PDN) design considerations, thermal design considerations, estimating power consumption, and a power consumption summary are also included in this design.
2 System Overview

The AM57x EVM kit includes the following features:

- **Processor Module Board:**
  - Sitara™ AM5728 processor
  - TPS659037 power management (PMIC)
  - 2 GB DDR3L
  - 4 GB eMMC
  - Micro SD card
  - 3x USB 3.0 HUB
  - USB 2.0 (micro)
  - Full size HDMI connector
  - eSATA connector
  - 2 GB Ethernet ports
  - Audio input and output
  - 20-pin ARM JTAG

- **LCD Module Board:**
  - 7-inch WVGA 800 × 480 LCD with capacitive touchscreen from one stop displays
  - Five user push buttons
  - One camera interface that connects to one of the six available video input ports on the AM572x
  - One mini PCI Express card slot
  - One COM8 WiLink8 wireless connector

- **Camera Module Board:**
  - 3 megapixel camera sensors

- **Included Accessories:**
  - Quick start guide
  - HDMI cable
  - USB-to-Serial debug cable
  - Micro SD card with Processor SDK

The AM57x EVM is shown in Figure 1. For detailed user information on the AM57x EVM, refer to the TMDXEVMAM57x Tool Folder.

![Figure 1. AM57x EVM (Processor Module, LCD Module, Camera Module)
**3 AM57x**

The AM57x is high performance computing platform, containing multiple heterogeneous cores, including:

- Up to Dual ARM® Cortex®-A15, C66x DSP, ARM Cortex-M4, SGX544 graphics, and quad core PRU-ICSS—Flexibility to assign tasks to core most optimal to meet its needs.
- USB3.0, PCIe, SATA, Gb Ethernet—multiple high speed interface options for feature rich products.
- Quad core PRU-ICSS—enables most comprehensive set of industrial communication protocols to date.
- HD video acceleration, HDMI, display subsystem, graphics, and video inputs—allows for very rich user interfaces.

There are four devices in the AM57x family, as shown in **Figure 2**. More information on each of these devices, including datasheets, technical reference manuals, and application notes can be found on the AM57x Product folders:

- AM5728 Product Folder
- AM5726 Product Folder
- AM5718 Product Folder
- AM5716 Product Folder

---

**Figure 2. AM57x Product Family**
4 Power Management Integrated Circuit (PMIC)

The TPS659037 is an integrated power management IC with 7 switch-mode power supply regulators, 7 linear regulators, and other functions used for power management. The PMIC handles the system reset by utilizing both cold and warm resets, and contains GPIO outputs to control external regulators or switches. The PMIC also provides interrupts to the processor to notify it of a number of events or faults.

The TPS659037 is optimized to power an AM57x system, utilizing a one-time-programmable (OTP) memory in order to configure platform settings such as boot voltages, power sequencing, and other default state. There are two OTP configurations of the TPS659037 to supply the AM57xx processors in different ways, and the PMIC and processor must be connected correctly in order to meet the voltage, current, and sequencing requirements of the processor. A simplified block diagram of the power management solution for AM572x using TPS659037 is shown in Figure 3.

The TPS659037 User's Guide to Power AM572x and AM571x (SLIU011B) describes these connections, as well as the OTP settings of the two different PMIC configurations.

Figure 3. AM57x Product Family
5 Power Distribution Network (PDN)

Power Delivery Network (PDN)

PDN performances were not considered as important information in the early days of printed circuit board (PCB) design. However, in today’s platforms that use lower voltage, higher current, and reduced voltage noise margins, PDN performance must be modeled early on in the PCB design process. PDN performance must then be optimized to meet the specified device requirements with an overall objective of supplying a noise-free and stable voltage to the application processor. Figure 1 presents a break-down model of a complete PDN network from the Voltage Resource Manager (VRM) to the application processor.

Several variables can affect the ability of a PCB design to meet the requirement for each power net. The AM572x General Purpose Evaluation Module Power Simulations Application Report (SPRABY8) addresses the effects the printed circuit board (PCB) structure and associated parasitic components have on the power supply characteristics, and provides recommended modeling techniques and power-delivery components.

6 Thermal Design Considerations

For some use cases, the AM57x is capable of dissipating its generated heat without the use additional components, such as heat sinks or fans. However, during high performance use cases or in extreme environments, overheating is a concern. Overheating can be avoided by employing thermal management techniques in the system design.

Thermal management ensures every silicon device on the board works within its allowable operating junction temperature. Failure to maintain a junction temperature within the range specified reduces operating lifetime, reliability, and performance—and may cause irreversible damage to the system. The product design cycle must include thermal analysis to verify that the operating junction temperature of the device is within functional limits. If the temperature is too high, component- or system-level thermal enhancements are required to dissipate the heat from the system.

Refer to AM57x Thermal Considerations for systems based on AM57x.
7 Estimating Power Consumption

The Power Estimation Tool (PET) allows users to gain insight into the power consumption of the AM57x Sitara™ Processors. The tool includes the ability for the user to choose multiple application scenarios and understand the power consumption as well as how advanced power saving techniques can be applied to further reduce overall power consumption.

PET spreadsheet is comprised of two parts:

- The input part of the spreadsheet is the mechanism in which users input device parameters needed for their application. Parameters include environmental configurations, DDR configurations, Operating Performance Point, dual voltage IO voltage and use case input.
- The output part of the spreadsheet contains the information on SoC power consumption based on power calculations in the spreadsheet. The output report which includes voltage, current and power will be shown in AM57x power consumption section.

The data presented in the PET spreadsheet are based on measurements performed on AM57x silicon, as well as estimates. For more information on the AM57x Power Estimation Tool, refer to the following links: AM572x Power Estimation Tool and AM571x Power Estimation Tool

8 Power Consumption Summary

The AM57x Power Consumption Summaries discuss the power consumption for common system application usage scenarios for the AM57x Sitara™ Processors. The metrics contained in this document serve to give users a better understanding of AM57x active power behaviors -- making it easier to determine a suitable configuration to meet a given power budget. Power consumption is highly dependent on the individual user’s application; however, this document focuses on providing several AM57x application use case scenarios and the environment settings that were used to perform such power measurements. This collection of real power measurements was measured on a TI power measurement hardware platform with a high-precision digital multimeter. The AM57x Power Consumption Summaries are available at the following links: AM572x Power Consumption Summary and the AM571x Power Consumption Summary.

9 Software

Software for the AM57x EVM is available by downloading the Processor SDK.
## Table 1. Test Results

<table>
<thead>
<tr>
<th>No.</th>
<th>TEST NAME</th>
<th>STATUS</th>
<th>No.</th>
<th>TEST NAME</th>
<th>STATUS</th>
<th>No.</th>
<th>TEST NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Audio input</td>
<td>PASS</td>
<td>16</td>
<td>Mem (transitions)</td>
<td>PASS</td>
<td>31</td>
<td>Reset button</td>
<td>PASS</td>
</tr>
<tr>
<td>2</td>
<td>Audio output</td>
<td>PASS</td>
<td>17</td>
<td>mPCIe</td>
<td>PASS</td>
<td>32</td>
<td>RTC</td>
<td>PASS</td>
</tr>
<tr>
<td>3</td>
<td>Backlight</td>
<td>PASS</td>
<td>18</td>
<td>mSATA</td>
<td>PASS</td>
<td>33</td>
<td>Temperature</td>
<td>PASS</td>
</tr>
<tr>
<td>4</td>
<td>Bootloader</td>
<td>PASS</td>
<td>19</td>
<td>PMIC REVISION ID</td>
<td>PASS</td>
<td>34</td>
<td>Touchscreen</td>
<td>PASS</td>
</tr>
<tr>
<td>5</td>
<td>Camera</td>
<td>PASS</td>
<td>20</td>
<td>PMIC Long Press Configuration</td>
<td>PASS</td>
<td>35</td>
<td>UART header</td>
<td>PASS</td>
</tr>
<tr>
<td>6</td>
<td>COM8</td>
<td>PASS</td>
<td>21</td>
<td>PMIC BOOT0=LOW</td>
<td>PASS</td>
<td>36</td>
<td>USB (eSATA)</td>
<td>PASS</td>
</tr>
<tr>
<td>7</td>
<td>DDR3</td>
<td>PASS</td>
<td>22</td>
<td>PMIC BOOT1-LOW</td>
<td>PASS</td>
<td>37</td>
<td>USB alone</td>
<td>PASS</td>
</tr>
<tr>
<td>8</td>
<td>eMMC</td>
<td>PASS</td>
<td>23</td>
<td>PMIC LDO4 REGS</td>
<td>PASS</td>
<td>38</td>
<td>USB Dual Bottom Port</td>
<td>PASS</td>
</tr>
<tr>
<td>9</td>
<td>eSATA</td>
<td>PASS</td>
<td>24</td>
<td>LDO4_CTRL (0x156)</td>
<td>PASS</td>
<td>39</td>
<td>USB Dual Top Port</td>
<td>PASS</td>
</tr>
<tr>
<td>10</td>
<td>Ethernet eth0 (top)</td>
<td>PASS</td>
<td>25</td>
<td>LDO4_VOLTAGE (0x157)</td>
<td>PASS</td>
<td>40</td>
<td>USB Client</td>
<td>PASS</td>
</tr>
<tr>
<td>11</td>
<td>Ethernet eth1 (bot)</td>
<td>PASS</td>
<td>26</td>
<td>LDO4_CTRL DISABLED</td>
<td>PASS</td>
<td>41</td>
<td>USER LEDs</td>
<td>PASS</td>
</tr>
<tr>
<td>12</td>
<td>Fan</td>
<td>PASS</td>
<td>27</td>
<td>Power buttons interrupts</td>
<td>PASS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>HDMI audio</td>
<td>PASS</td>
<td>28</td>
<td>POWER OFF</td>
<td>PASS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>HDMI video</td>
<td>PASS</td>
<td>29</td>
<td>User push buttons</td>
<td>PASS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>JTAG</td>
<td>PASS</td>
<td>30</td>
<td>REBOOT</td>
<td>PASS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Revision History

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

<table>
<thead>
<tr>
<th>Changes from Original (October 2015) to A Revision</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Changed design resources links to correct locations</td>
<td>1</td>
</tr>
</tbody>
</table>

---
IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Texas Instruments Incorporated (‘TI’) reference designs are solely intended to assist designers ("Designer(s)") who are developing systems that incorporate TI products. TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.

TI’s provision of reference designs and any other technical, applications or design advice, quality characterization, reliability data or other information or services does not expand or otherwise alter TI’s applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such reference designs or other items.

TI reserves the right to make corrections, enhancements, improvements and other changes to its reference designs and other items. Designer understands and agrees that Designer remains responsible for using its independent analysis, evaluation and judgment in designing Designer’s systems and products, and has full and exclusive responsibility to assure the safety of its products and compliance of its products (and of all TI products used in or for such Designer’s products) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to its applications, it has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any systems that include TI products, Designer will thoroughly test such systems and the functionality of such TI products as used in such systems. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

Designers are authorized to use, copy and modify any individual TI reference design only in connection with the development of end products that include the TI product(s) identified in that reference design. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other 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 to use such products or services, or a warranty or endorsement thereof. Use of the reference design or other items described above 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.

TI REFERENCE DESIGNS AND OTHER ITEMS DESCRIBED ABOVE ARE PROVIDED “AS IS” AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNERS AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS AS DESCRIBED IN A TI REFERENCE DESIGN OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

TI’s standard terms of sale for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm) apply to the sale of packaged integrated circuit products. Additional terms may apply to the use or sale of other types of TI products and services.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer’s non-compliance with the terms and provisions of this Notice.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2016, Texas Instruments Incorporated