This document details the implementation of a BOM-optimized discrete power solution for the AM437x processor with a minimal number of discrete ICs and basic feature set. The solution represents a baseline for a discrete power solution that can be extended for additional features of the AM437x processor.

The high-performance AM437x processor requires 4 different voltage rails with specific power-on and power-off sequences. The TLV family of devices offers a low cost power solution for the AM437x with simple RC delays to handle the required sequencing. The TLV62565 step-down converter provides the 3.3-V rail and the TLV62080 provides the 1.1-V rail, while two TLV702xx low drop out regulators (LDOs) provide the 1.5-V and 1.8-V rails. A TLV803M voltage supervisor is also included in the power solution to keep the processor in reset until all rails are operational and to reset the processor when input power is lost.

This document provides a reference for connectivity between these discrete ICs and the AM437x.

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1 Power Requirements

The discrete power solution is designed for the following system requirements:

- AM437x simplified power sequencing with RTC feature disabled
- VDD_MPU and VDD_CORE: OPP100
- No dynamic voltage and frequency scaling (DVFS)
- MPU clock frequency up to 600 MHz
- Dual voltage IO VDDSHVx: 3.3 V

Figure 1 shows a block diagram of the TLV family of devices and AM437x interface. A detailed circuit schematic detailing the power solution and sequence is found in Figure 3.

The AM437x power requirements are listed in Table 1.

![Functional Block Diagram Powering AM437x](image)

Figure 1. Functional Block Diagram Powering AM437x

### Table 1. AM437x Power Requirements

<table>
<thead>
<tr>
<th>Power-Up Sequence</th>
<th>Power-Down Sequence</th>
<th>Discrete ICs</th>
<th>Power Supply</th>
<th>Output Voltage (V)</th>
<th>AM437x</th>
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</tr>
<tr>
<td>1</td>
<td>3</td>
<td>TLV62565</td>
<td>Adjustable</td>
<td>3.3</td>
<td>VDDA3P3V_USB0/1, VDDS3P3V/IOLDO, VDDSHV1−11</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3 V ±5%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>TLV70215</td>
<td>1.5</td>
<td>1.5</td>
<td>VDDS_DDR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 V ±5%</td>
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<td>2</td>
<td>TLV70218</td>
<td>1.8</td>
<td>1.8</td>
<td>VDDS_RTC, VDDA_ADC0/1, VDDS_SRAM_CORE_BG, VDDS_SRAM_MPU_BB, VDDS_PLL_DDR, VDDS_PLL_CORE_LCD, VDDS_PLL_MPU, VDDS_OSC, VDDA1P8V_USB0/1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.8 V ±5%</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>TLV803M</td>
<td>Adjustable</td>
<td>1.1</td>
<td>VDD_CORE, VDD_MPU, CAP_VDD_RTC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.1 V ±4%</td>
</tr>
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</table>

The TLV62565 and TLV62080 step-down converters and the TLV702xx LDOs meet the power requirements. In order to power up the AM437x in the right sequence, RC delay circuits are implemented between the 3.3-V rail and 1.5-V/1.8-V rail as well as between the 1.5-V and 1.1-V rail.
1.1 Power-On Sequence

According to the AM437x data sheet (SPRS851), with RTC feature disabled and dual-voltage IOs configured as 3.3 V, the power up sequence should be as shown in Figure 2.

![Power-On Sequence Diagram](image)

The proper connections for this power-on sequencing are shown in Figure 3. When the 5-V rail is on, R4 and C6 provide an RC delay to the EN pin of the TLV62565. After the TLV62565 starts up, the 3.3-V output rail is connected to another RC delay, R7 and C8, which provides the EN signal for both LDOs. When the EN signal ramps up to the threshold voltage of the TLV70215 and TLV70218, these two ICs begin to start up. In this way, the 3.3-V rail and 1.5-V/1.8-V rails are powered on in the right sequence. Lastly, the EN pin of the TLV62080 is connected to the output of the 1.5-V rail by an RC delay, R8 and C10. In this way, the 1.1-V rail is powered on after the 1.5-V/1.8-V rails.
1.2 Power-Off Sequence

As shown in the AM437x data sheet, the preferred way to sequence power off is to have all the power supplies ramped down sequentially in the exact reverse order of the power-on sequence. In other words, the power supply that has been ramped up first should be the last one that is ramped down. This ensures no spurious current paths during the power-off sequence.

When using the simplified power-down sequence, there is no power-off requirement between the VDDS, VDDS_CLKOUT and VDDSHVx supplies. All supplies are ramped down together without any reliability concern.

The proper connections for this power-off sequencing are shown in Figure 3.

2 Schematic

Figure 3 shows the circuit schematic detailing the external components required by the optimized discrete solution to achieve the 3.3-, 1.5-, 1.8- and 1.1-V power rails required by the AM437x. In addition, Figure 3 shows the sequencing circuits with RC delays that achieve the proper power-on, power-off, and PWRONRSTn sequencing required by the AM437x.

Figure 3. Powering and Sequencing Circuit for AM437x Requirements
3 Waveforms

The following waveforms demonstrate that the power-on and power-off sequences of the discrete devices meet the requirements of the AM437x.

Figure 4 shows the power-on sequence for the 5-V, 3.3-V, 1.5-V and 1.1-V voltage rails.

Figure 4. Power-On Sequence with Converter Rails

Figure 5 shows the power-on sequence for all the required power supplies for AM437x.

Figure 5. Power-On Sequence for AM437x
After all the power rails are on, the PORZn signal is pulled high about 200 ms later, as shown in Figure 6.

Figure 6. Power-On Sequence with PORZn Signal

Figure 7 shows the power-off sequence of the voltage rails with the PORZn signal. When the PORZn signal goes low, the processor enters the reset state and all rails are safe to turn off as their input voltage drops.

Figure 7. Power-Off Sequence with PORZn Signal
The voltage rail’s power-off sequence is shown in Figure 8.

![Image showing power-off sequence]

Figure 8. Power-Off Sequence with All Power Supply Rails

4 Bill of Materials

The bill of materials for the BOM-optimized discrete power solution is listed in Table 2.

<table>
<thead>
<tr>
<th>Count</th>
<th>RefDes</th>
<th>Value</th>
<th>Description</th>
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<th>MFR</th>
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<td>47uF</td>
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<td>Std</td>
<td>Std</td>
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<td>4</td>
<td>C2, C7, C9, C11</td>
<td>10uF</td>
<td>Capacitor, ceramic, 6.3-V, X5R, 20%</td>
<td>0603 Std</td>
<td>Std</td>
<td>Std</td>
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<td>Capacitor, ceramic, 10-V, X5R, 20%</td>
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<td>C8, C10</td>
<td>2.2uF</td>
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<td>0603 GRM18861A225KE34</td>
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<td>39.2k</td>
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<td>Std</td>
<td>Std</td>
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<td>170k</td>
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<td>Std</td>
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<td>U4</td>
<td>TLV803M</td>
<td>IC, 3pin voltage supervisors</td>
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<tr>
<td>1</td>
<td>U5</td>
<td>TLV62080</td>
<td>IC, 1.2-A sync. step-down converter</td>
<td>SON-8 TLV62080D5G</td>
<td>Ti</td>
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</tr>
</tbody>
</table>
5 Power-Up Sequence for TLV70215 and TLV70218

There could be a small difference of startup time between the TLV70215 and TLV70218, but this is unimportant for the AM437x. Though they are from the same LDO family (TLV702xx) and share the same EN signal, it cannot be ensured that the TLV70215 and TLV70218 start simultaneously.

There are two factors leading to the different startup time of the two devices. The first factor is the different EN threshold voltages of the two devices. Though the TLV70215 and TLV70218 are from the same LDO family, parameter variation leads to possibly different EN thresholds, as shown in Figure 9.

![Figure 9. Potentially Different EN Thresholds of the two Devices](image)

Secondly, the delay time after receiving the EN signal is also different. With a very sharp EN signal, the influence of different EN thresholds is insignificant. However, even with the same EN signal and without any threshold difference, the delay time of the TLV70215 (Delay1) and the TLV70218 (Delay2) is possibly different, as shown in Figure 10.

![Figure 10. Potentially Different Delays with Sharp EN Signal](image)

These two factors create the small startup time difference between the TLV70215 and TLV70218. It is very difficult to eliminate the different startup time since parameter variation between the devices cannot be controlled accurately. However, this small difference has no influence on the power-on sequence for the AM437x.
6 Slew Rate Requirement

To maintain the safe operating range of the internal ESD protection devices, it is recommended to limit the maximum slew rate of all supplies to be less than 1.0E +5 V/s.

![Slew Rate Graph](image)

**Figure 11. Power Supply Slew Rate Requirement**

The TLV62565 for the 3.3-V rail has a fixed startup time of about 250 µs. The TLV62080 for the 1.1-V rail has a fixed soft start time of 100 µs. Both meet the requirement of a slew rate < 1E +5 V/s.

The 1.8-V and 1.5-V rails only have current limit during startup and not a controlled slew rate. The slew rate of the output voltage is decided by the output capacitor and current limit. On the 1.8-V rail for example, the startup time should be greater than 18 µs. From the data sheet of the TLV70218 (SLVSAG6), the maximum current limit is 860 mA. According to the following equation, using an output capacitor larger than 8.6 µF at the 1.8-V output meets the slew rate requirement.

\[
\frac{I_{\text{Current\_limit}}}{C_{\text{OUT}}} = \frac{V_{\text{OUT}}}{\text{Slew Rate}}
\]

Thus, the minimum output capacitor for TLV702xx is calculated according to Equation 1.

7 Supporting AM437x 1-GHz Operation

The AM437x Sitara processors support up to 1000-MHz CPU frequency. For running the processor at 1 GHz with the discrete power solution, the VDD_MPU power supply should be powered by a 1.325-V power supply. **Figure 12** shows the block diagram of supporting 1-GHz processor operation. The VDD_MPU power supply is powered at 1.325-V by an additional TLV62565 step-down converter. The same enable signal from the RC delay output of 1.5-V DDR power supply can be used for enabling the TLV62565.

![Block Diagram](image)

**Figure 12. Block Diagram of 1-GHz Mode Support**
8 Conclusion

The TLV62565 and TLV62080 step-down converters combined with the TLV70218 and TLV70215 LDOs provide a BOM-optimized, discrete power solution for the AM437x. This reference design demonstrates the external components of the discrete ICs to provide the required voltage rails and RC delay circuits that meet the power-on and power-off sequencing requirements of the AM437x processor. This document can be used as a reference for choosing a series of discrete devices for powering the AM437x.

9 References

1. TLV62565, 1.5-A High Efficiency Step-Down Converter in SOT23-5 Package data sheet (SLVSBC1)
2. TLV62080, 1.2 A High Efficient Step-Down Converter in 2x2 mm SON Package data sheet (SLVSAK9)
3. TLV702xx, 300-mA, Low-IQ, Low-Dropout Regulator data sheet (SLVSAG6)
4. TLV803M, 3-Pin Voltage Supervisors with Active-Low, Open-Drain Reset data sheet (SBVS157)
5. AM437x, AM437x Sitara Processors data sheet (SPRS851)

Revision History

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

Changes from Original (September 2014) to A Revision

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<td>Replaced Figure 3. ......................</td>
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CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

Concerning EVMs Including Radio Transmitters:
This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:
(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:
Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:
Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables
Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

3.3.1 Notice for EVMs delivered in Japan: Please see http://www.tij.co.jp/lds/lt_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lds/lt_ja/general/eStore/notice_01.page

3.3.2 Notice for Users of EVMs Considered “Radio Frequency Products” in Japan: EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan.
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.
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1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

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3.3.3 Notice for EVMs for Power Line Communication: Please see http://www.tij.co.jp/lnds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lnds/ti_ja/general/eStore/notice_02.page

3.4 European Union
3.4.1 For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):
This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 EVM Use Restrictions and Warnings:
4.1 EVMs ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
4.3 Safety-Related Warnings and Restrictions:
4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. Accuracy of Information: To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.
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