This document helps the user create a design-in a Stellaris® ARM® Cortex™-M3 MCU into a system requiring a wide-input voltage range and is concerned about maintaining high efficiency and long battery life. This particular design allows for an input voltage between 1.8 V to 5.5 V.

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1 Introduction

This reference design is for the Stellaris® ARM® Cortex™-M3 MCU family and accounts for voltage and current requirements, given below. The microcontrollers require only a single voltage supply, so no sequencing is needed. The operating input voltage for this reference design is between 1.8 V and 5.5 V, thus allowing users operating from a battery supply to benefit from the complete battery capacity. This design is optimized for wide-input voltage range, a small solution size and low component count.

For more information and other reference designs, see the Reference section at the end of this document or visit www.ti.com/processorpower.

1.1 Features

- 1.8-V to 5.5-V input voltage range
- Fixed 3.3-V output eliminates need for external voltage-setting resistors
- The TPS63001 is capable of driving up to 800 mA when operating in boost mode
- The TPS63031 is capable of driving up to 500 mA when operating in boost mode
- High efficiency (up to 94%)
- Low quiescent current (less than 50 µA)
- Small QFN packages: 2.5 mm × 2.5 mm (TPS63031) or 3 mm x 3 mm (TPS63001)

2 Requirements

The power requirements for each Stellaris® ARM® Cortex™-M3 MCU family are listed below.

For more information and other reference designs, visit www.ti.com/processorpower.

<table>
<thead>
<tr>
<th>DEVICE FAMILY</th>
<th>PIN NAME(S)</th>
<th>VOLTAGE (V)</th>
<th>(I_{\text{MAX}}) (mA)</th>
<th>TOLERANCE</th>
<th>SEQUENCING ORDER</th>
<th>TIMING DELAY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM3S100 series</td>
<td></td>
<td>VDD</td>
<td>3.3</td>
<td>170</td>
<td>±10%</td>
<td></td>
<td>Internal regulator supplies power to device core</td>
</tr>
<tr>
<td>LM3S300 series</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LM3S600 series</td>
<td></td>
<td></td>
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<tr>
<td>LM3S800 series</td>
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<td>LM3S1000 series</td>
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<td>LM3S2000 series</td>
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<tr>
<td>LM3S3000 series</td>
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<tr>
<td>LM3S5000 series</td>
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<table>
<thead>
<tr>
<th>DEVICE FAMILY</th>
<th>PIN NAME(S)</th>
<th>VOLTAGE (V)</th>
<th>(I_{\text{MAX}}) (mA)</th>
<th>TOLERANCE</th>
<th>SEQUENCING ORDER</th>
<th>TIMING DELAY</th>
<th>COMMENTS</th>
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<td></td>
<td>VDD</td>
<td>3.3</td>
<td>225</td>
<td>±10%</td>
<td></td>
<td>Internal regulator supplies power to device core</td>
</tr>
<tr>
<td>LM3S8000 series</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM3S9000 series</td>
<td></td>
<td>VDD</td>
<td>3.3</td>
<td>150</td>
<td>±10%</td>
<td></td>
<td>Internal regulator supplies power to device core</td>
</tr>
<tr>
<td>LM3S2B93</td>
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<td></td>
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<td></td>
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<td>LM3S2B2793</td>
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<tr>
<td>LM3S5B91</td>
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<td>LM3S5791</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

(1) The  \(I_{\text{MAX}}\) currents listed are “worst case” expected values.
3 Description of Power Solution

Using a buck-boost topology for battery driven applications enables users to fully benefit from the available charge given from the chemistry.

The described TPS630xx devices belong to a fully integrated family of converters, which regulate automatically the preset output voltage over the entire input voltage range of 1.8 V - 5.5 V.

For a fixed 3.3-V output, the converter operates in step-down mode for the time, where the input voltage is greater than 3.3 V. Once the input voltage undercuts the required 3.3-V, the converter automatically transitions into boost mode without the need of any external control signals or circuitry.

The buck-boost converter is based on a fixed frequency pulse-width-modulation (PWM) controller using synchronous rectification to obtain maximum efficiency. At low load currents the converter enters a Power Save mode to maintain high efficiency over a wide load current range. The Power Save mode can be disabled using the PS/SYNC pin, forcing the converter to operate at a fixed switching frequency.

During shutdown, the load is disconnected from the battery.

If the power budget of the TPS63001 is needed, but solution size is critical, see the TPS63011 with the available WCSP package.
3.1 **Power Supply Option 1: TPS63031**

TPS63031 supports 500 mA when operating in boost mode (Vin > 2.4V) and greater 800 mA when working in step-down mode (Vin = 3.6 V to 5.5 V). The overall solution size, the entire efficiency as well as the provided power budget make the converter an ideal fit for portable, battery driven applications. For a more detailed description of the device characteristics as well as functionality, see to the device data sheet.

The device can be evaluated by itself using the evaluation module TPS63030EVM-417. The EVM contains by default the adjustable device TPS63030. In order to evaluate the 3.3 V version, replace the device U1 on the PCB with TPS63031. Furthermore, R1 must be replaced with a 0-Ω resistor; the R2 position remains open.

The following description as well as the results are taken from the TPS63030EVM-417 Users Guide.

### 3.1.1 Schematic

![Figure 1. TPS63030EVM-417 Schematic](image-url)
3.1.2 List of Materials TPS63030EVM-417

<table>
<thead>
<tr>
<th>QTY</th>
<th>REF DES</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>PART NUMBER</th>
<th>MFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>C1, C2, C3</td>
<td>10 µF</td>
<td>Capacitor, ceramic, 6.3-V, X7R, 10%</td>
<td>0603</td>
<td>GRM188R60J106ME84D</td>
<td>Murata</td>
</tr>
<tr>
<td>1</td>
<td>C4</td>
<td>0.1 µF</td>
<td>Capacitor, ceramic, 6.3-V, X7R, 10%</td>
<td>0603</td>
<td>GRM188R70J104KA01B</td>
<td>Murata</td>
</tr>
<tr>
<td>0</td>
<td>C5</td>
<td>Open</td>
<td>Capacitor, ceramic, 6.3-V, X7R, 10%</td>
<td>0603</td>
<td>GRM188R60J106ME84D</td>
<td>Murata</td>
</tr>
<tr>
<td>1</td>
<td>L1</td>
<td>1.5 µH</td>
<td>Inductor, SMT, 1.3-A, 110-mΩ</td>
<td>0.118 x 0.118</td>
<td>LPS3015-152MLB</td>
<td>Coilcraft</td>
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<tr>
<td>3</td>
<td>R1, R3, R4</td>
<td>1 MΩ</td>
<td>Resistor, chip, 1/16-W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>180 kΩ</td>
<td>Resistor, chip, 1/16-W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td>IC, dc/dc converter</td>
<td>DSK</td>
<td>TPS63030DSK</td>
<td>TI</td>
<td></td>
</tr>
</tbody>
</table>

3.1.3 Test Results TPS63031

Following results are all based on the TPS63030EVM-417 settings and just represent an example of the functionality and performance.

Figure 2 represents the device behavior during the start-up phase. Figure 3 demonstrates the small output ripple at a typical load of 150 mA.
3.2 **Power Supply Option 2: TPS63001**

TPS63001 supports 800 mA when operating in boost mode (Vin > 2.4 V) and greater 1200 mA when working in step-down mode (Vin = 3.6 V to 5.5 V). The overall solution size, the entire efficiency as well as the provided power budget make the converter an ideal fit for portable, battery driven applications. For a more detailed description of the device characteristics as well as functionality, see the device data sheet.

The device can be evaluated by itself using the evaluation module TPS63000EVM-148. The EVM contains by default the adjustable device TPS63000. In order to evaluate the 3.3 V version, replace the device U1 on the PCB with TPS63001. Furthermore, R1 must be replaced with a 0-Ω resistor; the R2 position remains open.

The following description as well as the results are taken from the TPS63000EVM-148 Users Guide.

### 3.2.1 Schematic

![Figure 4. PMP4778 Reference Design Schematic](UDG-09083)

### 3.2.2 List of Materials PMP4778

<table>
<thead>
<tr>
<th>REF DES</th>
<th>QTY</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>PART NUMBER</th>
<th>MFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1, C2, C3</td>
<td>3</td>
<td>10 µF</td>
<td>Capacitor, ceramic, 6.3V, X5R, 20%</td>
<td>0603</td>
<td>C1608X5R0J106M</td>
<td>TDK</td>
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<tr>
<td>L1</td>
<td>1</td>
<td>2.2 µH</td>
<td>Inductor, SMT, 1.5A, 110 mΩ</td>
<td>0.116” x 0.116”</td>
<td>LPS3015-222ML</td>
<td>Coilcraft</td>
</tr>
<tr>
<td>R1</td>
<td>1</td>
<td>0 Ω</td>
<td>Resistor, chip, 1/16W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>U1</td>
<td>1</td>
<td></td>
<td>IC, buck-boost converter</td>
<td>QFN-10</td>
<td>TPS63001DRC</td>
<td>TI</td>
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</table>
3.2.3 Test Results TPS63001

The input and output startup waveforms are shown in Figure 5 through Figure 10. The output ripple voltages are shown in Figure 11 through Figure 13. Figure 14 through Figure 16 shows the transient responses. The switching node waveforms are shown in Figure 17 through Figure 19. The efficiency versus the output current is shown in Figure 20.

![Figure 5. Startup](image1.png)

![Figure 6. Startup](image2.png)

![Figure 7. Startup](image3.png)

![Figure 8. Startup](image4.png)
1.8V - 5.5V Input, 3.3V Output, High Efficiency DC/DC Converter

**Description of Power Solution**

![Figure 9. Startup](image)

- **Figure 9. Startup**
  - $V_{\text{IN}} = 5\, \text{V}$
  - $I_{\text{LOAD}} = 1.3\, \text{A}$
  - $V_{\text{OUT}}$ (1 V/div)
  - $V_{\text{IN}}$ (1 V/div)
  - $t = \text{Time} - 1\, \text{ms/div}$

![Figure 10. Startup](image)

- **Figure 10. Startup**
  - $V_{\text{IN}} = 5\, \text{V}$
  - No load
  - $V_{\text{OUT}}$ (1 V/div)
  - $V_{\text{IN}}$ (1 V/div)

![Figure 11. Output Ripple Voltage](image)

- **Figure 11. Output Ripple Voltage**
  - $V_{\text{IN}} = 1.8\, \text{V}$
  - $I_{\text{LOAD}} = 440\, \text{mA}$
  - $V_{\text{RIPPLE}}$ (50 mV/div)
  - $t = \text{Time} - 0.5\, \text{us/div}$

![Figure 12. Output Ripple Voltage](image)

- **Figure 12. Output Ripple Voltage**
  - $V_{\text{IN}} = 3.3\, \text{V}$
  - $I_{\text{LOAD}} = 1.2\, \text{A}$
  - $V_{\text{RIPPLE}}$ (50 mV/div)
  - $t = \text{Time} - 0.5\, \text{us/div}$
VIN = 1.8V
Load Step 200 mA to 400 mA

IOUT
(200 mA/div)

VOUT
(200 mV/div)

t – Time – 2 ms/div

Figure 13. Output Ripple Voltage

VIN = 3.3V
Load Step 600 mA to 1.2 A

IOUT
(500 mA/div)

VOUT
(100 mV/div)

t – Time – 2 ms/div

Figure 15. Load Transient

VIN = 5V
Load Step 600 mA to 1.2 A

IOUT
(500 mA/div)

VOUT
(100 mV/div)

t – Time – 2 ms/div

Figure 16. Load Transient
Figure 17. Switching Node Waveform

Figure 18. Switching Node Waveform

Figure 19. Switching Node Waveform

Figure 20. Efficiency vs Output Current
4 Inductor Selection

Table 4 lists inductor series from different suppliers that have been used with TPS6303x converters. Table 5 lists inductor series from different suppliers that have been used with TPS6300x converters.

<table>
<thead>
<tr>
<th>VENDOR</th>
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<tr>
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<td>LP3015</td>
</tr>
<tr>
<td></td>
<td>EPL3010</td>
</tr>
<tr>
<td>Murata</td>
<td>LQH3NP</td>
</tr>
<tr>
<td>Taiyo Yuden</td>
<td>NR3015</td>
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</table>

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>INDUCTOR SERIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coilcraft</td>
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<td>Murata</td>
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<td>Taiyo Yuden</td>
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<td>TDK</td>
<td>VLF3215</td>
</tr>
<tr>
<td></td>
<td>VLF4012</td>
</tr>
</tbody>
</table>

For a more detailed description of how to configure the inductor based on the individual needs, see the related device data sheets.
5 Capacitor Selection

5.1 Input Capacitor

A minimum effective value of 4.7 μF for input capacitor is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and PGND pins of the device is recommended.

5.2 Bypass Capacitor (TPS6303x only)

To make sure that the internal control circuits are supplied with a stable low noise supply voltage, a capacitor can be connected between VINA and GND. Using a ceramic capacitor with a value of 0.1 μF is recommended. The value of this capacitor should not be higher than 0.22 μF.

5.3 Output Capacitor

For the output capacitor, it is recommended to use small ceramic capacitors placed as close as possible to the VOUT and PGND pins of the device. If, for any reason, the application requires the use of large capacitors which cannot be placed close to the device, using a smaller ceramic capacitor in parallel to the large one is recommended. This small capacitor should be placed as close as possible to the VOUT and PGND pins of the device.

To get an estimate of the recommended minimum output capacitance, Equation 1 can be used.

\[
C_{\text{OUT}} = 5 \times L \times \frac{\mu F}{\mu H}
\]

A capacitor with a value in the range of the calculated minimum should be used. This is required to maintain control loop stability. There are no additional requirements regarding minimum ESR. There is also no upper limit for the output capacitance value. Larger capacitors will cause lower output voltage ripple as well as lower output voltage drop during load transients.

6 General Layout Considerations

The following guidelines shall be understood as applicable to power designs as such and are not specific to the power solution outlined in this document.

As for all switching power supplies, the layout is an important step in the design. A proper function of the device demands careful attention to PCB layout. It is essential to take good care of the board layout to get the specified performance. In case the layout is not well done, the regulator could show poor line and/or load regulation and stability issues, as well as EMI problems. It is critical to provide a low-inductance, low-impedance ground path. Therefore, use wide and short traces for the main current paths. The input capacitor, inductor, and output capacitor should be placed physically as close as possible to the device terminals. The most important reason aside keeping the noise at a low level is the fail safe operation of the solution. Any distance added between the components will increase the value of the parasitics, which could result into greater voltage levels inside the device than the chip actually would be able to withstand. In other words, keeping the external components connected closely will prevent the device from failures through parasitics.

Connect the GND terminal of the device to the thermal-pad land of the PCB and use this pad as a star point. Use a common power-GND node and a different node for the signal GND to minimize the effects of ground noise. Connect these ground nodes together to the thermal-pad land (star point) underneath the device. Keep the common path to the GND terminal, which returns the small signal components and the high current of the output capacitors, as short as possible to avoid ground noise.
# References

## Table 6. Related Documents

<table>
<thead>
<tr>
<th>DEVICE NUMBER</th>
<th>TI LITERATURE NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
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<tr>
<td>TPS63001</td>
<td>SLVS520</td>
<td>High Efficient Single Inductor Buck-Boost Converter with 1.8-A Switch</td>
</tr>
<tr>
<td>TPS63031</td>
<td>SLVS696</td>
<td>High Efficient Single Inductor Buck-Boost Converter with 1-A Switch</td>
</tr>
<tr>
<td><strong>EVM USER'S GUIDES</strong></td>
<td></td>
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<td>TPS63000EVM-148</td>
<td>SLVU156</td>
<td>Using the TPS63000EVM</td>
</tr>
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<td>TPS63030EVM-417</td>
<td>SLVU275</td>
<td>Using the TPS63030EVM</td>
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