Reference Design

SLVA358A–October 2009–Revised April 2010

1.8V - 5.5V Input, 3.3V Output, High Efficiency DC/DC Converter

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 1. Stellaris® ARM® Cortex™-M3 MCU Family Power Requirements[(1)]

DEVICE FAMILY	PIN NAME(S)	VOLTAGE (V)	I_{MAX} (mA)	TOLERANCE	SEQUENCING ORDER	TIMING DELAY	COMMENTS
LM3S100 series LM3S300 series LM3S600 series LM3S800 series LM3S1000 series LM3S2000 series LM3S3000 series LM3S5000 series	VDD	3.3	170	±10%	–	–	Internal regulator supplies power to device core
LM3S6000 series LM3S8000 series	VDD	3.3	225	±10%	–	–	Internal regulator supplies power to device core
LM3S9000 series	VDD	3.3	150	±10%	–	–	Internal regulator supplies power to device core
LM3S2B93 LM3S2B2793 LM3S5B91 LM3S5791	VDD	3.3	100	±10%	–	–	Internal regulator supplies power to device core

(1) The I_{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

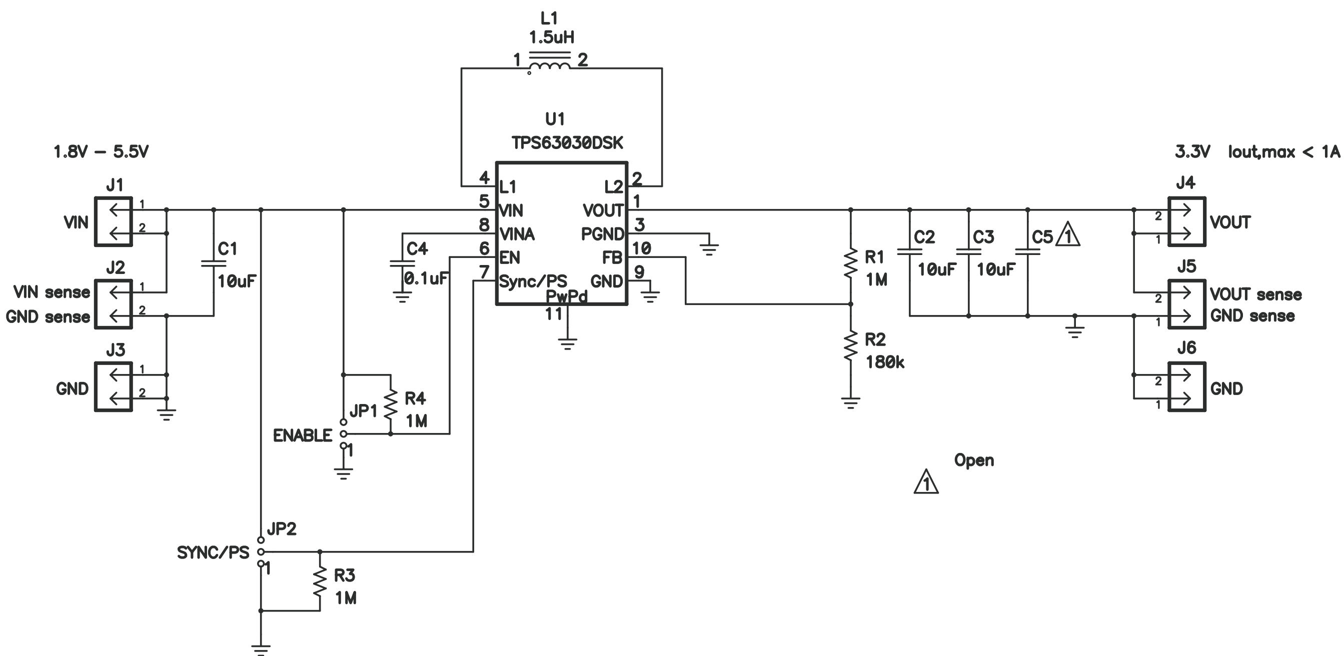


Figure 1. TPS63030EVM-417 Schematic

3.1.2 List of Materials TPS63030EVM-417

Table 2. List of Materials TPS63030EVM-417

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

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.

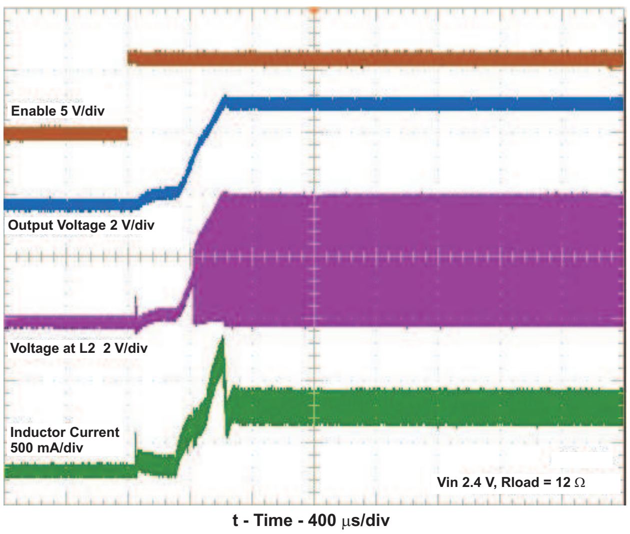


Figure 2. Turn ON into Load, V_{IN} = 2.2 V

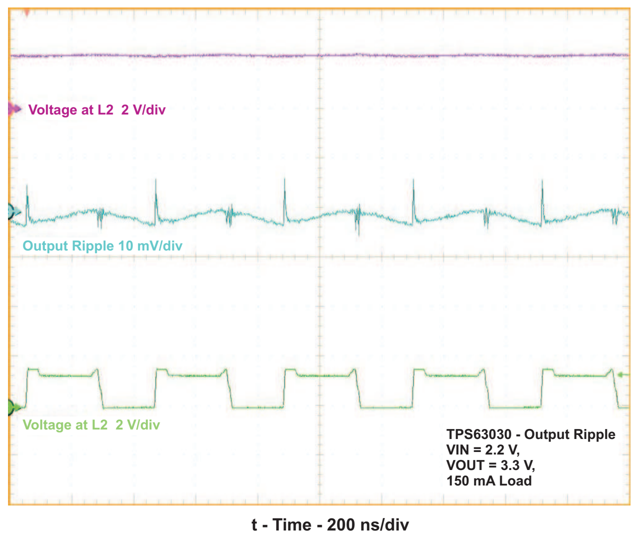


Figure 3. Output Ripple, V_{IN} = 2.2 V

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

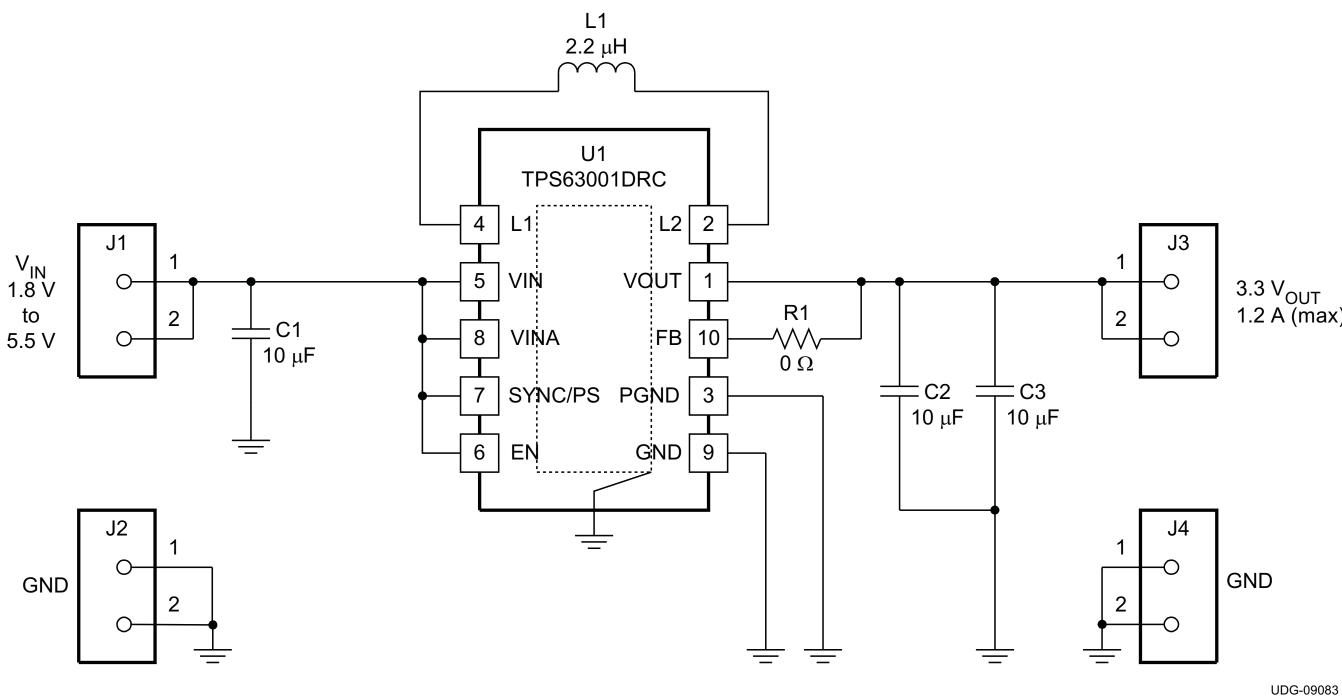


Figure 4. PMP4778 Reference Design Schematic

3.2.2 List of Materials PMP4778

Table 3. List of Materials PMP4778

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

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.

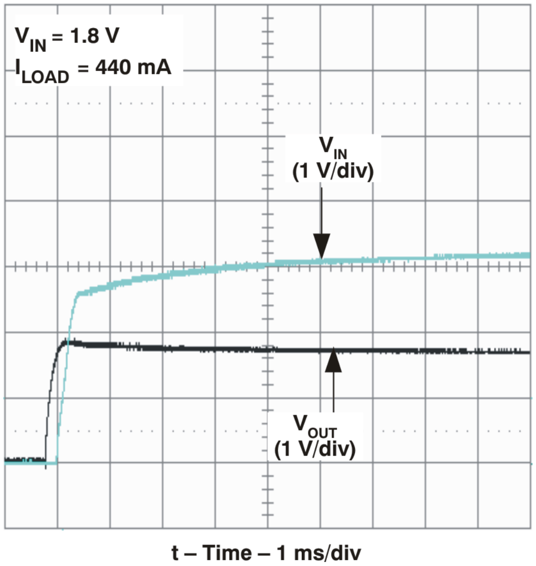


Figure 5. Startup

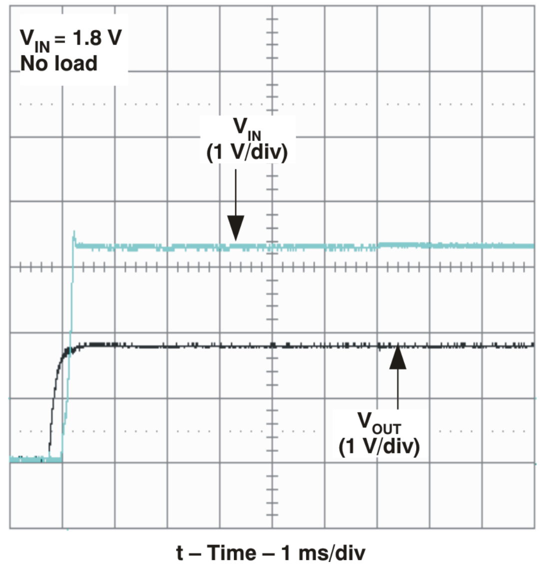


Figure 6. Startup

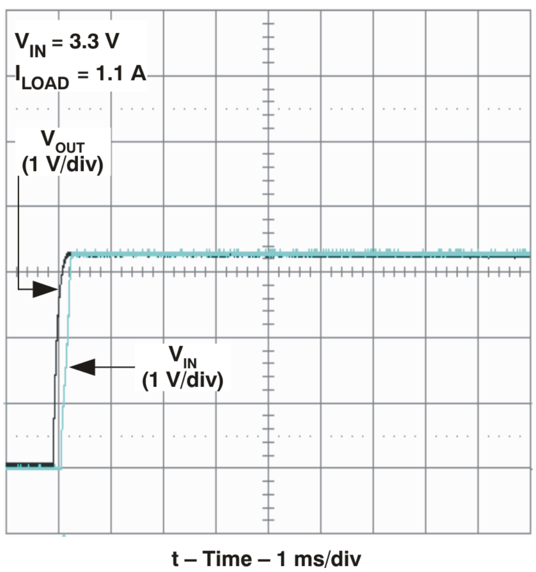


Figure 7. Startup

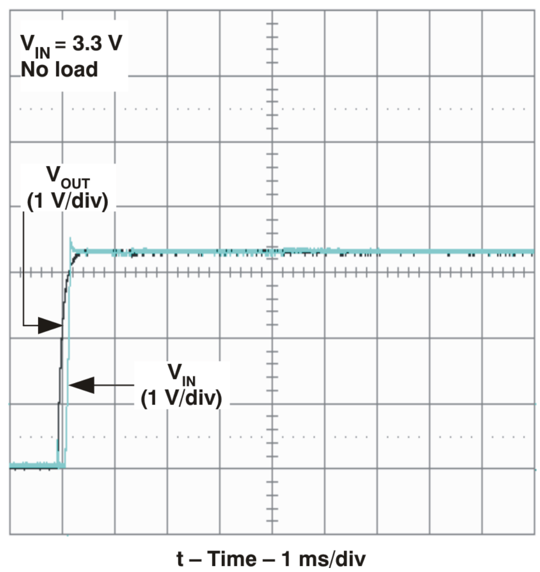


Figure 8. Startup

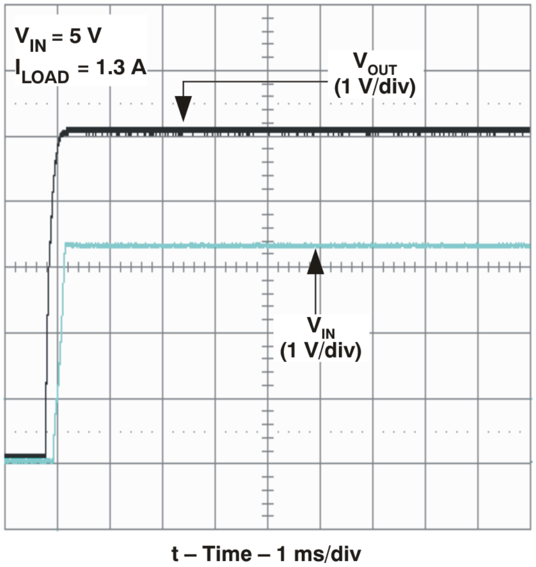


Figure 9. Startup

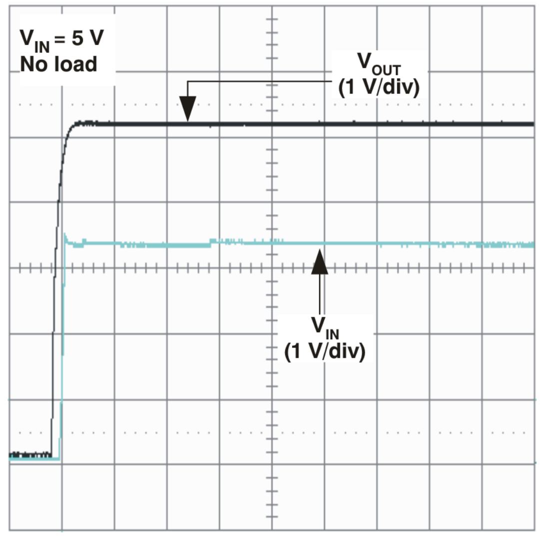


Figure 10. Startup

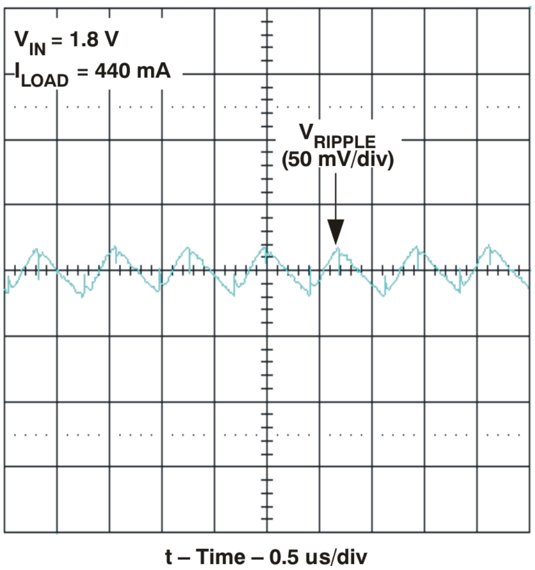


Figure 11. Output Ripple Voltage

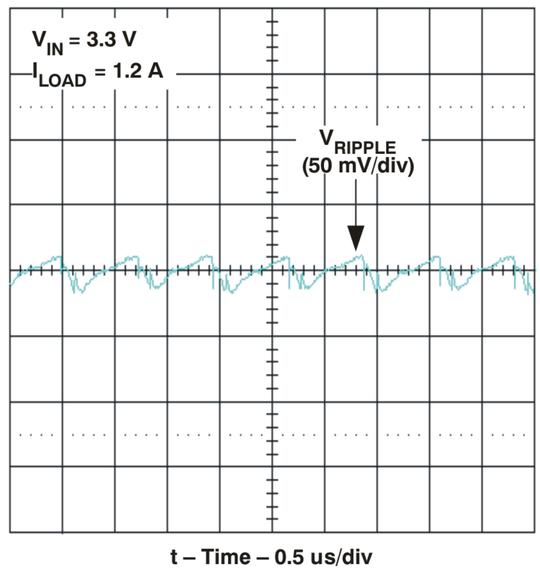
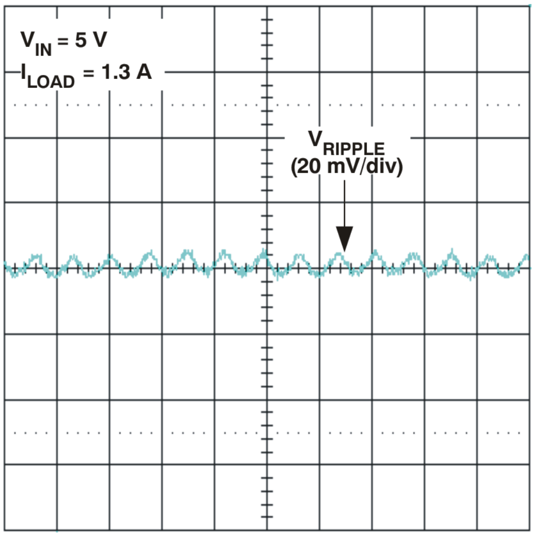
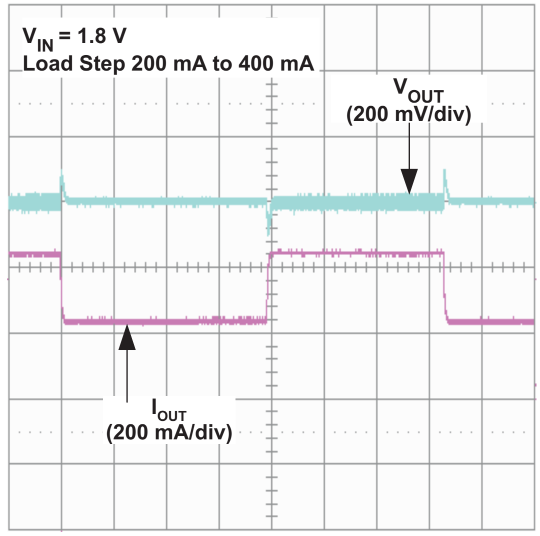


Figure 12. Output Ripple Voltage



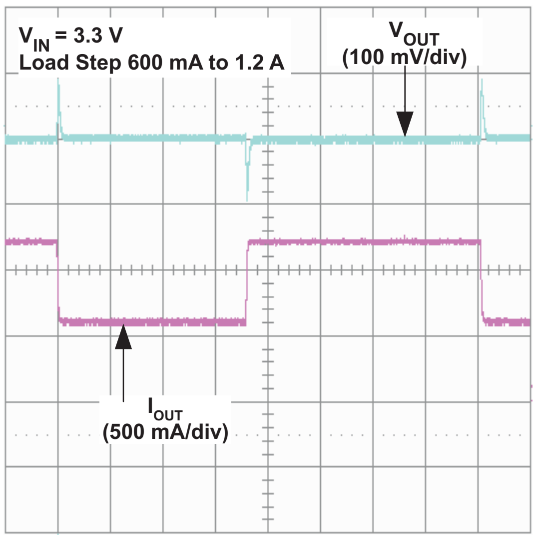
t – Time – 1 us/div

Figure 13. Output Ripple Voltage



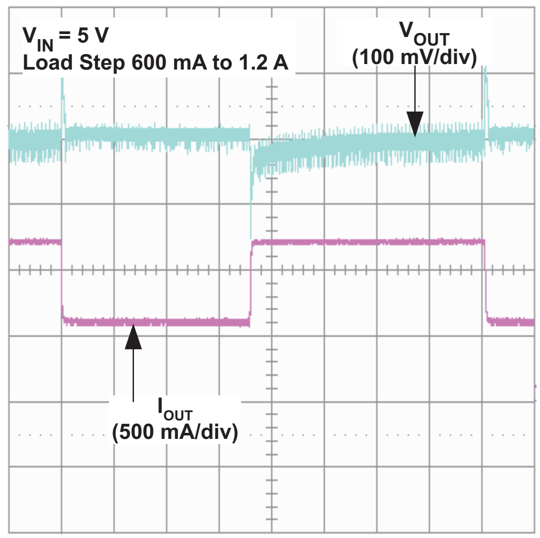
t – Time – 2 ms/div

Figure 14. Load Transient



t – Time – 2 ms/div

Figure 15. Load Transient



t – Time – 2 ms/div

Figure 16. Load Transient

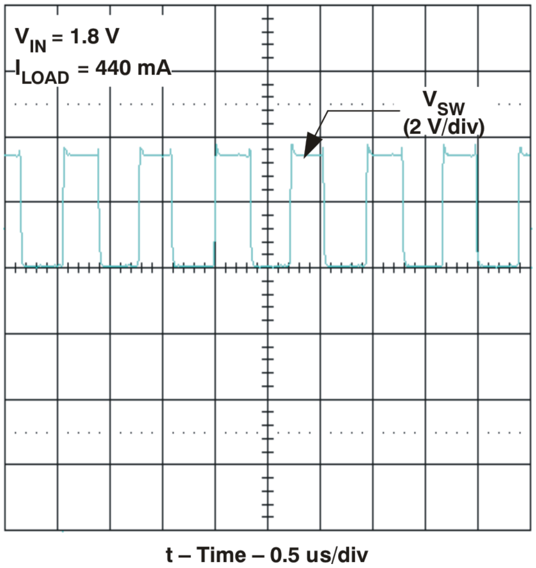


Figure 17. Switching Node Waveform

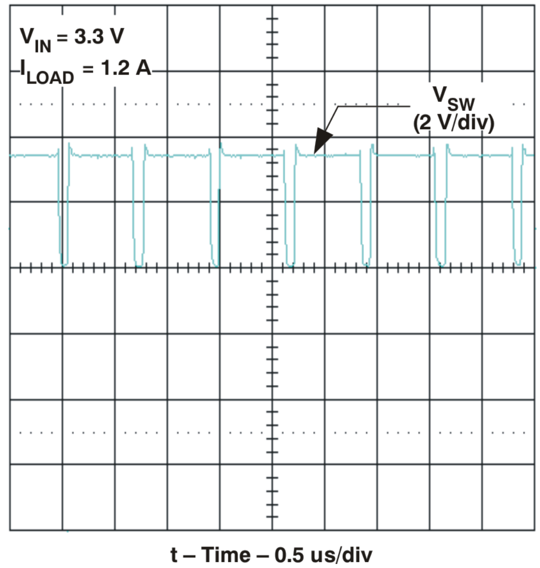


Figure 18. Switching Node Waveform

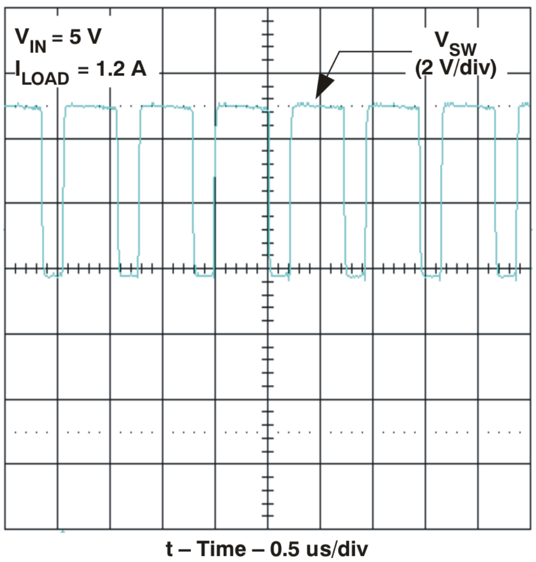


Figure 19. Switching Node Waveform

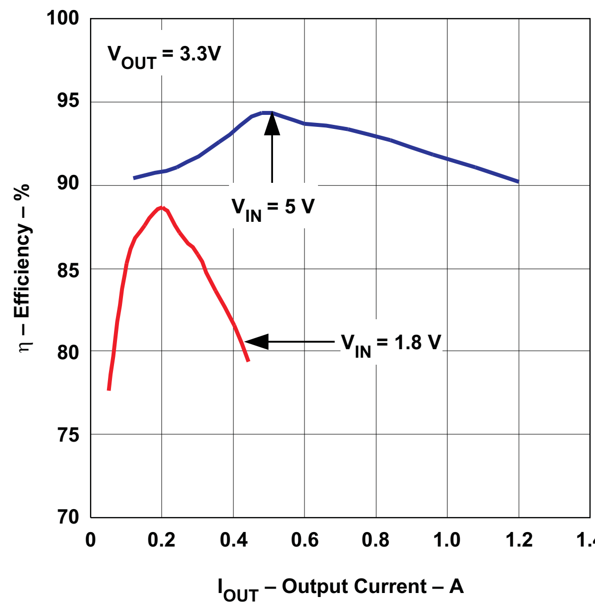


Figure 20. Efficiency vs Output Current

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 4. TPS6303x List of Inductors

VENDOR	INDUCTOR SERIES
Coilcraft	LP3015
	EPL3010
Murata	LQH3NP
Taiyo Yuden	NR3015

Table 5. TPS6300x List of Inductors

VENDOR	INDUCTOR SERIES
Coilcraft	LP3015
	LP4012
Murata	LQH3NP
Taiyo Yuden	NR3015
TDK	VLF3215
	VLF4012

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 can not 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.

$$C_{OUT} = 5 \times L \times \frac{\mu F}{\mu H} \tag{1}$$

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.

7 References

Table 6. Related Documents

DEVICE NUMBER	TI LITERATURE NUMBER	DESCRIPTION
DATA SHEETS		
TPS63001	SLVS520	High Efficient Single Inductor Buck-Boost Converter with 1.8-A Switch
TPS63031	SLVS696	High Efficient Single Inductor Buck-Boost Converter with 1-A Switch
EVM USER'S GUIDES		
TPS63000EVM-148	SLVU156	Using the TPS63000EVM
TPS63030EVM-417	SLVU275	Using the TPS63030EVM

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