AN13528

Using the DC-DC and LDO Features on the LPC553x/LPC55S3x Family

Rev. 2 — 20 February 2023 Application note

Document information

Information	Content
Keywords	AN13528, LPC553x/LPC55S3x, DCDC, LDO
Abstract	This application note provides a hardware design guide for the internal DC-DC converter and the internal LDO regulator on LPC553x/LPC55S3x devices.

1 Introduction

This application note provides a hardware design guide for the internal DC-DC converter and the internal LDO regulator on LPC553x/LPC55S3x devices. This document explains how to choose external components and summarizes the connection for all packages properly. The main part of the document focuses on critical parameters of external components and their implication of incorrect selection, including a PCB design example of the external component.

The internal LDO allows the MCU to use an external regulation element (for example, external DC-DC converter). It helps you to simplify complex application designs with more MCUs. This feature expands the functionality of LPC553x/LPC55S3x and enables you to use an external power supply, often used in more complex applications.

2 Theory and usage of DC-DC converters

DC-DC converters are used in portable electronic devices, such as cellular phones and laptop computers, which are supplied primarily from batteries. Such electronic devices often contain several subcircuits. These subcircuits have their own voltage level requirement different from the level supplied by a battery or an external supply (sometimes higher or lower than the supply voltage). The battery voltage lowers because its stored energy is drained. Switched DC-DC converters offer a method to increase the voltage from a partially lowered battery voltage and save space (instead of using multiple batteries to achieve the same goal).

Most DC-DC converter circuits also regulate the output voltage. Exceptions include high-efficiency LED power sources, which are DC-DC converters that regulate the current flowing through the LEDs, and simple charge pumps, which double or triple the output voltage.

Switching converters, such as buck converters in LPC553x/LPC55S3x, provide much higher power efficiency than DC-DC converters and linear regulators (simpler circuits that lower the voltage by dissipating the excess power as heat), but do not step up the output current.

3 Theory and use of LDO regulators

A linear voltage regulator is a circuit that takes in variable input voltage and provides continuously controlled, steady, low-noise DC output voltage. Linear voltage regulators require a large voltage drop between input and output to function correctly. This requires a high-voltage-input power supply and results in low-power efficiency.

LDO (Low-Dropout) regulators are DC linear voltage regulators that regulate the output voltage even when the supply voltage is very close to the output voltage. The main advantages of LDOs over DC-DC converters include the absence of switching noise, smaller device size, and greater design simplicity.

The disadvantage is that, unlike switching regulators, linear DC regulators must dissipate power (and therefore heat) across the regulation device to regulate the output voltage.

4 Hardware design guide of internal DC-DC converters and LDO regulators

This chapter summarizes the hardware requirements for external components used for a proper functionality of internal DC-DC converters. It contains recommendations of appropriate component selection and PCB drawings.

The LPC553x/LPC55S3x family consists of six internal regulators (including a DC-DC converter), which are supplied by the main external supply domain (VBAT 1.8 V – 3.6 V) and (VDD_MAIN 1.8 V – 3.6 V).

The connection of all external components and the MCU needed for a proper DC-DC functionality is shown in Figure 1.

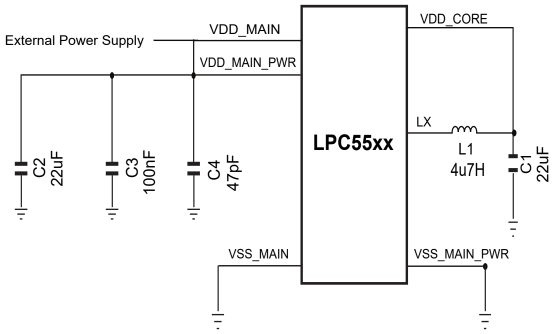

Figure 1. External parts for DC-DC converter

Table 1 summarizes pin names and numbers for all packages.

Table 1. List of pin names and numbers for internal DC-DC converter

Symbol	100-pin QFP100	64-pin QFP64_AFE	48-pin QFN48	Description
VDD_MAIN	48	32	24	Power-control system
VDD_MAIN_PWR	47	32	24	High current/high transient current
VDD_CORE	38	24	18	Supply of DC-DC output stage. DC-DC core supply (references and regulation stages)
LX	46	31	23	DC-DC converter power stage output
VSS_MAIN	45	30	22	The star ground connection is managed to the PCB ground plane
VSS_MAIN_PWR	44	29	22	The star ground connection is managed to the PCB ground plane

Table 2 summarizes typical values and limitations for external components of the DC-DC internal converter.

Table 2. External parts

Part	Min	Typ	Max	Unit
C1	10	22 (X5R or X7R)	47	µF
C2	10	22 (X5R or X7R)	47	µF
C3	80	100 (X5R or X7R)	120	nF
C4	38.7	47 (COG)	56.2	pF
L1	3.87	4.7	10	µH

The connection of all external components and the MCU needed for a proper function of an internal LDO is shown in Figure 2.

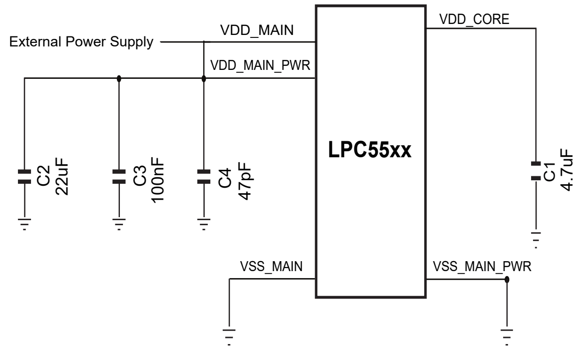

Figure 2. External parts for using internal LDO

Table 3 summarizes pin names and numbers for all packages.

Table 3. List of pin names and numbers for internal LDO regulator

Symbol	100-pin QFP100	64-pin QFP64_AFE	48-pin QFN48	Description
VDD_MAIN	48	32	24	Power control system
VDD_MAIN_PWR	47	32	24	High current/high transient current
VDD_CORE	38	24	18	Supply of DC-DC output stage. DC-DC core supply (references and regulation stages)
VSS_MAIN	45	30	22	The star ground connection is managed to the PCB ground plane
VSS_MAIN_PWR	44	29	22	The star ground connection is managed to the PCB ground plane

Table 4 summarizes typical values and limitations for external components of the internal LDO regulator.

Table 4. External parts

Part	Min	Typ	Max	Unit
C1	-	4.7 (X5R or X7R)	-	μF
C2	10	22 (X5R or X7R)	47	μF
C3	80	100 (X5R or X7R)	120	nF
C4	38.7	47 (COG)	56.2	pF

4.1 Input-decoupling capacitors

The 100 nF and 47 pF ceramic capacitors are the input-decoupling capacitors for the DC-DC converter. The 10 mF (or 20 mF) input ceramic capacitor is used to decouple and power the internal DC-DC converter. All the decoupling capacitors must be placed close to the pin. For the capacitors, there is no ESR value restriction.

4.2 Output filter capacitor

This capacitor sets the voltage ripple value. The minimum value of the output capacitor is 10 μF, which is necessary for the correct functionality of the DC-DC converter. This capacitor also sets the voltage ripple value, which is essential for the USB power supply requirements.

If the value of the output capacitor is below 4.7 μF, the voltage ripple is higher and does not meet the requirements of the internal LDO. Values higher than 22 μF increase the possible noise current.

4.3 Power inductor

The typical inductor value for most application ranges from 3.7 μH to 5.6 μH. These values are chosen according to the desired ripple current.

At the expense of a higher output-voltage ripple, small-value inductors result in a higher output current slew rate, improving the load transient response of the converter. Larger values of inductors lower the ripple current and reduce the core magnetic hysteresis losses.

The power inductor is not used when using an internal LDO.

Table 5 summarizes the typical values and limitations of the power inductor.

Table 5. Power inductor

Parameter	Min	Typ	Max	Unit
Inductance value	3.7	4.7	5.6	μH
Saturation current	350	500	-	mA

4.3.1 Saturation current limitation

The minimum value of the saturation current is 350 mA. The typical and recommended value of the saturation current is 500 mA (or higher).

4.4 PCB guide line

To reduce the series resistance from the DC-DC inductor, keep the traces as thick and as short as possible. The ground between the inputs of capacitors C2, C3, and C4, the DC-DC ground pads, and the output capacitor C1 must be on the same plane. It is not possible to use a via or a strap connection. Figure 3 shows a proper DC-DC ground connection.

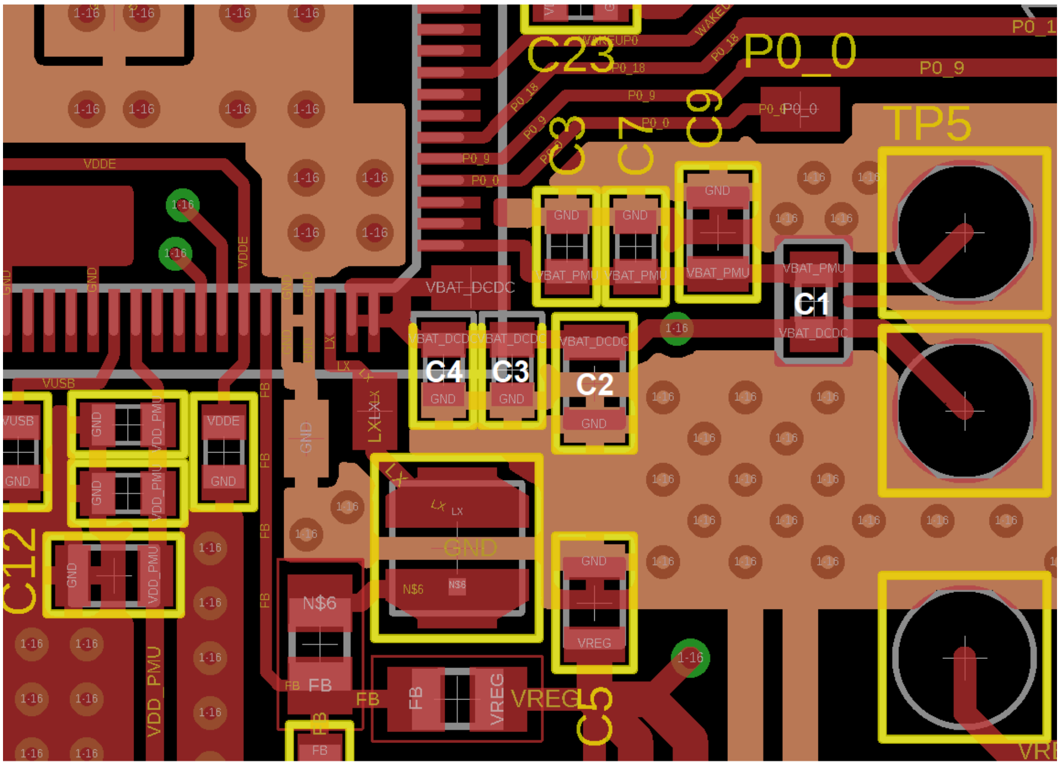

Figure 3. Ground connection

5 Conclusion

This application note summarizes all external components and PCB recommendations of the internal DC-DC converter and the internal LDO used in LPC553x/LPC55S3x. For proper functionality, follow these recommendations in your designs with LPC553x/LPC55S3x. Efficiency is often the main purpose of using a DC-DC converter.

The LPC553x/LPC55S3x family also uses internal LDO, which enables you to use an external power supply. This approach can be used in more complex applications, where the power supply is designed as an independent block.

The use of DC-DC converters increases the efficiency of the conversion from the battery voltage to a low supply voltage. On the other hand, the internal LDO has lower noise and few external components.

6 Revision history

Table 6 summarizes the changes done to this document since the initial release.

Table 6. Revision history

Revision number	Date	Substantive changes
2	20 February 2023	• Updated Figure 2 • Few editorial changes
1	23 May 2022	Replaced "Using the DCDC and LDO Features" with "Using the DC-DC and LDO Features on the LPC553x/LPC55S3x Family"

Table 6. Revision history*...continued*

Revision number	Date	Substantive changes
0	07 April 2022	Initial release

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