PCB design guide for XMC1000

XMC1000

About this document

Scope and purpose

This application note provides guidance on the layout of power and ground traces for the XMC1000 devices. It also gives recommendations on the placement and values of decoupling capacitors for the XMC1000 devices.

In chapter 1, a general overview of different packages for the XMC1000 family microcontroller is provided.

In chapter 2, the PCB design recommendations for the XMC1100, XMC1200 and XMC1300 are given.

In chapter 3, the PCB design recommendation for the XMC1400 is given.

Intended audience

This document is intended for anyone who is performing PCB layout for any XMC1000 devices.

Table of contents

1 Overview 2
1.1 Optimized ADC performance 2
2 PCB design recommendations for XMC1100, XMC1200, XMC1300 3
2.1 PCB layouts for TSSOP38 package 3
2.1.1 Application: general purpose application 3
2.1.2 Application: LED touch sense 4
2.1.3 Application: motor control and power conversion 4
2.2 PCB layouts for TSSOP-28 and TSSOP-16 packages 5
2.3 PCB layouts for VQFN24 and VQFN40 package 8
3 PCB design recommendation for XMC1400 10
3.1 Power supply de-coupling, ADC grounding and external oscillator 10
3.2 PCB layouts for VQFN40/48/64 and LQFP64 10
3.2.1 PCB layouts for XMC1400-VQFN40 11
3.2.2 PCB layouts for XMC1400-VQFN48 13
3.2.3 PCB layouts for XMC1400-VQFN64/LQFP64 15

1 Overview

The XMC1000 family is an ARM® Cortex™-M0 based 32-bit microcontroller family. The XMC1100, XMC1200 and XMC1300 series devices are available in TSSOP-16, TSSOP-28, TSSOP-38, VQFN-24 and VQFN-40 packages.

The XMC1100, XMC1200 and XMC1300 series microcontrollers have two internal oscillators, DCO1 and DCO2.

- DCO1 has a clock output of 64 MHz, and is used to generate the main clock, MCLK and fast peripheral clock, PCLK.
- DCO2 is used to generate the standby clock running at 32.768 kHz, and does not require an external oscillator.

The XMC1400 series devices are available in VQFN-40, VQFN-48, VQFN-64 and LQFP-64 packages. The XMC1400 series microcontroller also has internal oscillators, DCO1 and DCO2. The device also supports external crystals for system and real time clock/standby clock generation. This feature is for any user who requires higher clock accuracy.

- DCO1 has a clock output of 96 MHz, and is used to generate the main clock, MCLK and fast peripheral clock, PCLK.
- DCO2 is used to generate the standby clock running at 32.768 kHz.

This application note guides users on the routing of the power supply to the low pin count device of the XMC1000 family. It also provides guidance on external oscillator circuitry layout for the XMC1400 device. The correct board layout will help to achieve the best ADC performance and EMC behavior.

The document should be read in conjunction with the Infineon PCB design guidelines for microcontrollers (AP24026), which gives general design rule information for PCB design.

Note: This application note contains design recommendations from Infineon Technologies point of view. Effectiveness and performance of the final application implementation must be validated by the customer, based on dedicated implementation choices.

1.1 Optimized ADC performance

The TSSOP-16, TSSOP-28 and VQFN-24 package of the XMC1000 microcontroller has only two supply pins (VDDP / VDD and VSSP / VSS) to which all internal modules are connected. These are the embedded voltage regulator, the port pins, the ADC module and the oscillators in the XMC1000 microcontroller.

The performance of the ADC and the robustness of the oscillator will be reduced if power supply noise or pin activity noise are not properly de-coupled. For the TSSOP-38 package, there are four supply pins. The VDDP / VDD and VSSP / VSS pins are dedicated to power the ADC module while VDDP and VSSP pins are used to power the rest of the internal modules.

Proper de-coupling can be achieved by separating the ground traces in analog and digital groups. A star point connection should be considered at the pad of the VSSP / VSS pin of the TSSOP-16, TSSOP-28 and VQFN-24 package. The ADC reference voltage is connected to the VDDP / VDD pin. Hence, supply noise directly influences the ADC performance.

The ADC analog ground can be disturbed by noise injection from neighboring active pins driving high frequency signals from I^2C, PWM or the LED and Touch Sense unit. Good PCB layout will reduce the capacitance between those traces to a minimum.

This application note includes layout recommendations for optimized ADC performance.

2 PCB design recommendations for XMC1100, XMC1200, XMC1300

There are two reasons why microcontrollers can cause noise at the power supply. Firstly the synchronous clocked logic functions lead to peak current at the MCU clock frequency. Secondly, pulse pattern and clock output at any port pin will draw current at the pulse pattern's frequency. This sudden increase in peak current will cause the power supply to drop or oscillate. Hence, de-coupling capacitors are intended to buffer the charge needed to feed the required current pulses.

Similarly, noise on the power supply lines might also disturb the microcontroller. This noise can be filtered by the same de-coupling capacitor.

The figures in this section show the recommended PCB layout for different applications using TSSOP-38, TSSOP-28, TSSOP-16, VQFN-24 and VQFN-40 packages of the XMC1100, XMC1200 and XMC1300 microcontroller. By following the recommended PCB layout, the power supply is de-coupled and ADC performance is improved.

The recommended PCB layout for XMC1400's VQFN40, VQFN48, VQFN64 and LQFP64 packages are shown in Chapter 3.

2.1 PCB layouts for TSSOP38 package

In the following layout examples, C1 and C2 should both be at least 100 nF. Capacitors with low ESR (ceramic capacitors for example) are recommended.

2.1.1 Application: general purpose application

If the intended application is primarily for ADC measurement and some simple general purpose input/output toggling, then the following PCB layout is recommended.

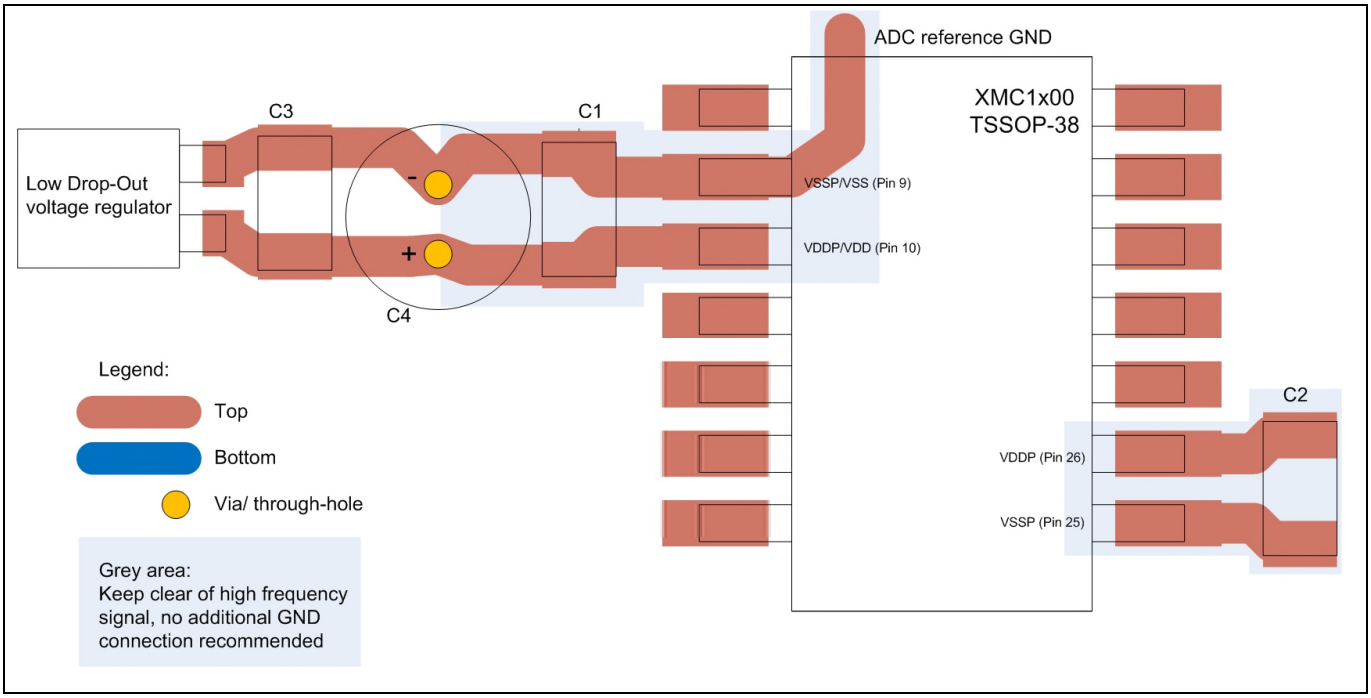

Figure 1 PCB layout for ADC and general GPIO application using TSSOP-38 package

Normally, there is a low drop-out voltage regulator to step down the input voltage to the operating voltage of the XMC1000 microcontroller. The electrolytic capacitor C4 at the output of the voltage regulator acts as a low

pass filter and reduces the ripple voltage of VDDP. C3 is the decoupling capacitor for the filtering of high frequency noise.

C1 acts as decoupling capacitor for ADC circuitry. C2 acts as the decoupling capacitor for the digital circuitry of the XMC1000 microcontroller. Any additional connection will bypass the decoupling capacitors C1 and C2 and will therefore reduce their effectiveness.

The grey areas shown in the figures should be kept clear of any GND connections and GND planes. Ensure that the decoupling capacitors C1 and C2 are placed as close to the pins as possible.

For the TSSOP-38 package, pin 10 (VDDP / VDD) and pin 26 (VDDP) are connected internally. Similarly, pin 9 (VSSP / VSS) is connected internally to pin 25 (VSSP). Hence, those pins do not need to connect externally.

The ADC reference GND connection is intended to be utilized in common mode with the ADC's input pins. Any additional connection to pin 9 (VSSP / VSS) in this figure will cause supply noise to be injected to the ADC's reference GND.

2.1.2 Application: LED touch sense

If the board is also to be used for driving an LED, then an additional VDDP copper trace should be routed from pin 10 (VDDP / VDD) to pin 26 (VDDP) of the TSSOP-38 package. As additional current needs to be supplied from the port pin to drive the LEDs, so an additional VDDP copper trace will increase the current carrying capability of the internal VDDP bonding wire.

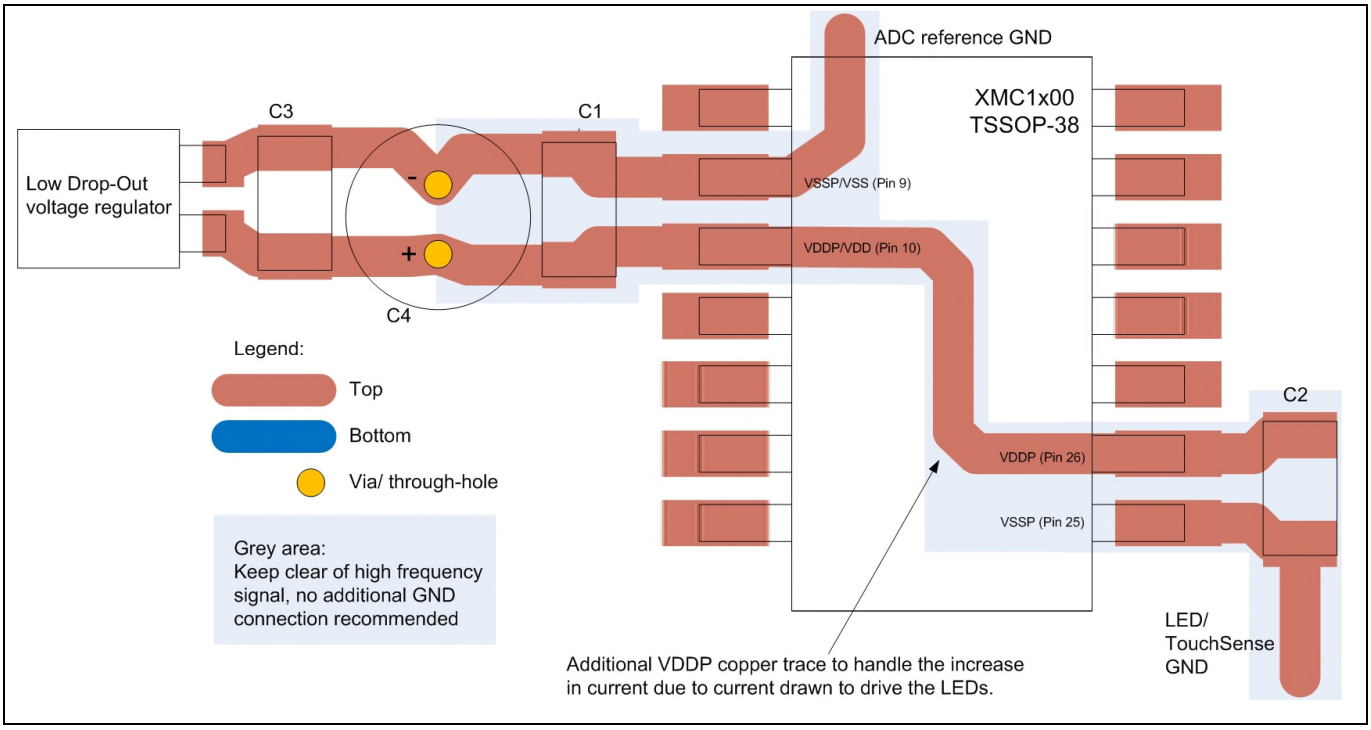

Figure 2 PCB layout for ADC and LED touch sense application using TSSOP-38 package

2.1.3 Application: motor control and power conversion

If the board is to be used for ADC and motor or power conversion applications, where high switching waveforms will be output from the CCU4 / CCU8 port, then the following PCB layout is recommended:

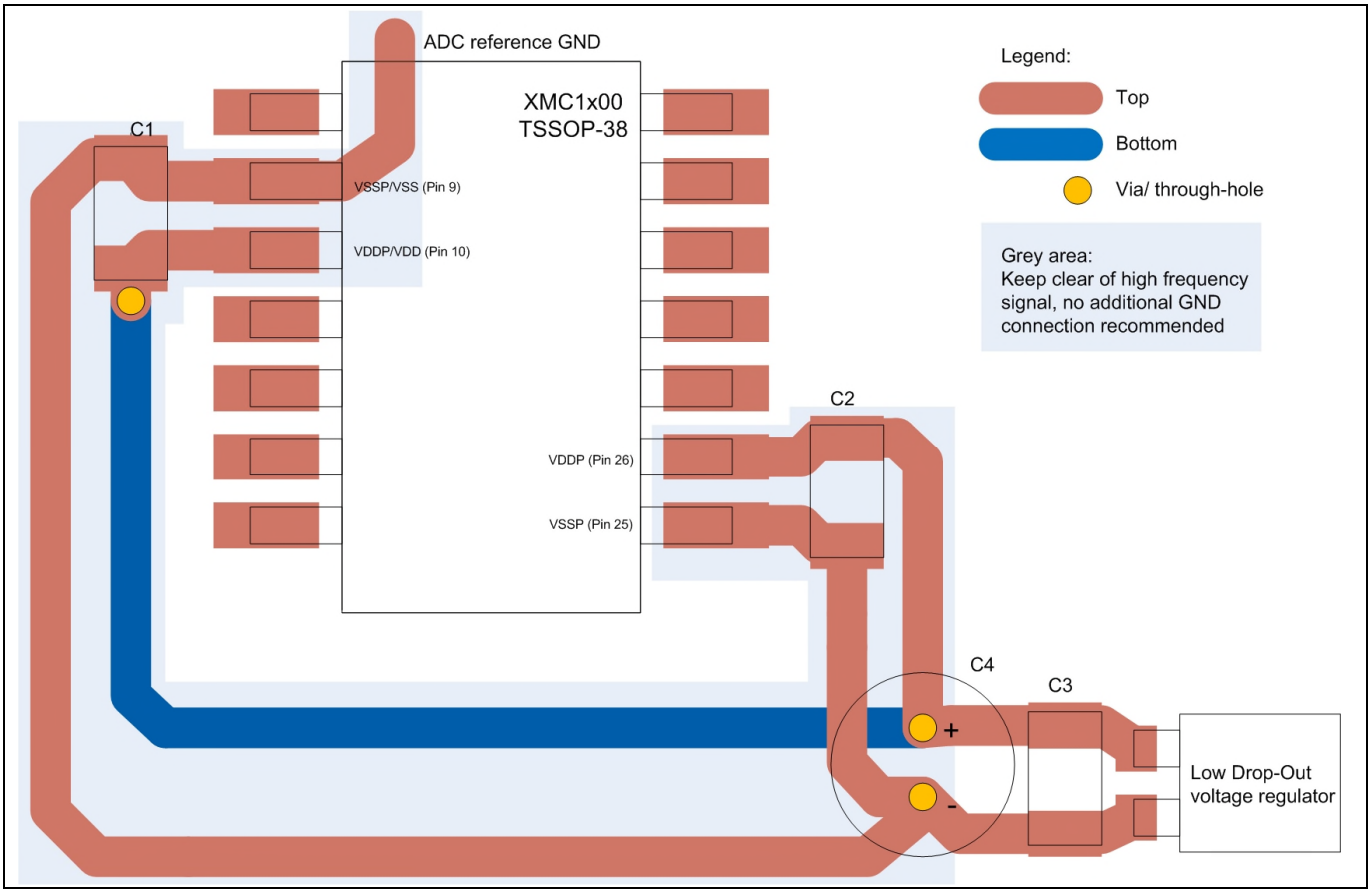

Figure 3 PCB layout for ADC and motor or power conversion application using TSSOP-38 package

At the negative terminal of the electrolytic capacitor C4, a star-point ground should be used. A digital ground trace will run from this star-point ground to VSSP (Pin 25) of the XMC1000 microcontroller. Another analog ground trace will also run from the negative terminal of C4 to VSSP / VSS (Pin 9) of the XMC1000 microcontroller. By using this star-point ground configuration, the interference of digital noise at VSSP (Pin 25) to the analog ground at VSSP / VSS (Pin 9) is minimized.

2.2 PCB layouts for TSSOP-28 and TSSOP-16 packages

In the following layouts, C2 should be set 100 nF and capacitors with low ESR (ceramic capacitors for example) are recommended.

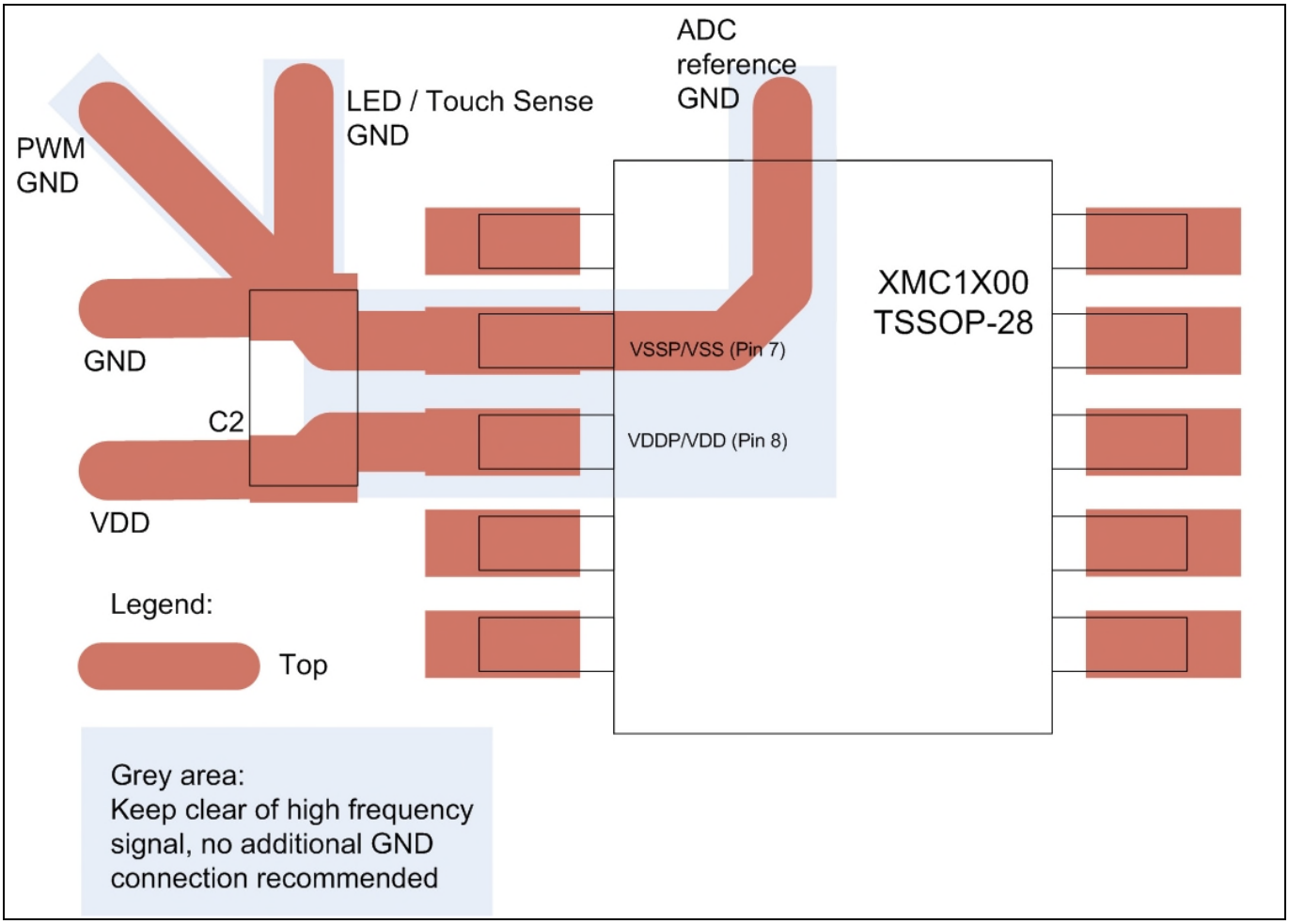

Figure 4 PCB layout for TSSOP-28 package

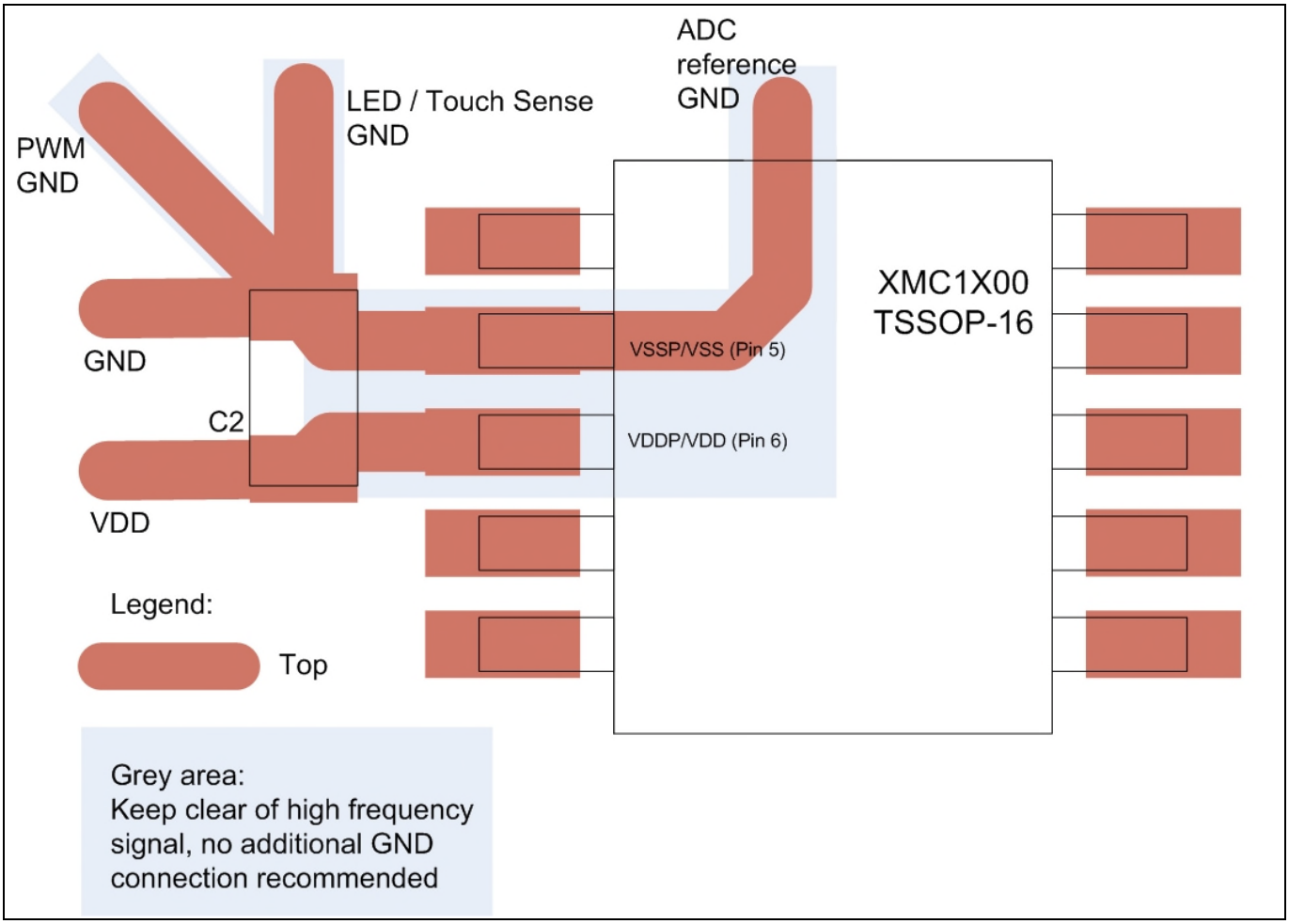

Figure 5 PCB layout for TSSOP-16 package

For TSSOP-28 and TSSOP-16 packages, there is only one pair of VDDP / VDD and VSSP / VSS pins, so a star-point ground is recommended at de-coupling capacitor C2.

A star configuration at the VSSP / VSS pin (for the TSSOP-16 and TSSOP-28 packages) is the least noisy connection for the ADC reference ground. This connection is best coupled to the ADC's reference voltage ground potential and is important for minimizing ADC errors.

From the star point ground, digital grounds (e.g. PWM ground, LED/Touch sense ground) and analog ground (ADC reference ground) are branched out individually to their circuitry.

The noise of the power supply (VDDP / VDD and VSSP / VSS) is filtered by the capacitor C2 in the TSSOP-28 and TSSOP-16 packages.

It must be ensured that the de-coupling capacitors C2 are placed as close to the pins as possible. It is also important to connect the power supply GND and VDD only at those traces shown in the figures. Any additional connection will bypass the de-coupling capacitor C2 and will therefore reduce its effectiveness. The grey areas shown in the figures should be kept clear of any GND connections and GND planes.

The ADC reference GND connection is intended to be used in a common mode with the ADC's input pins. Any additional connection to the power supply GND will cause supply noise to be injected to the ADC's reference GND. So, if LED/Touch sense ground is required on the application board, please use the star point ground configuration as shown.

2.3 PCB layouts for VQFN24 and VQFN40 package

In the following layouts, C2 should be set to 100 nF and capacitors with low ESR (ceramic capacitors for example) are recommended.

The exposed die pad of VQFN24 AND VQFN40 packages are connected internally to VSSP. For proper operation, it is mandatory to connect the exposed pad to the board ground. For thermal aspects, please refer to the Package and Reliability chapter of their datasheet.

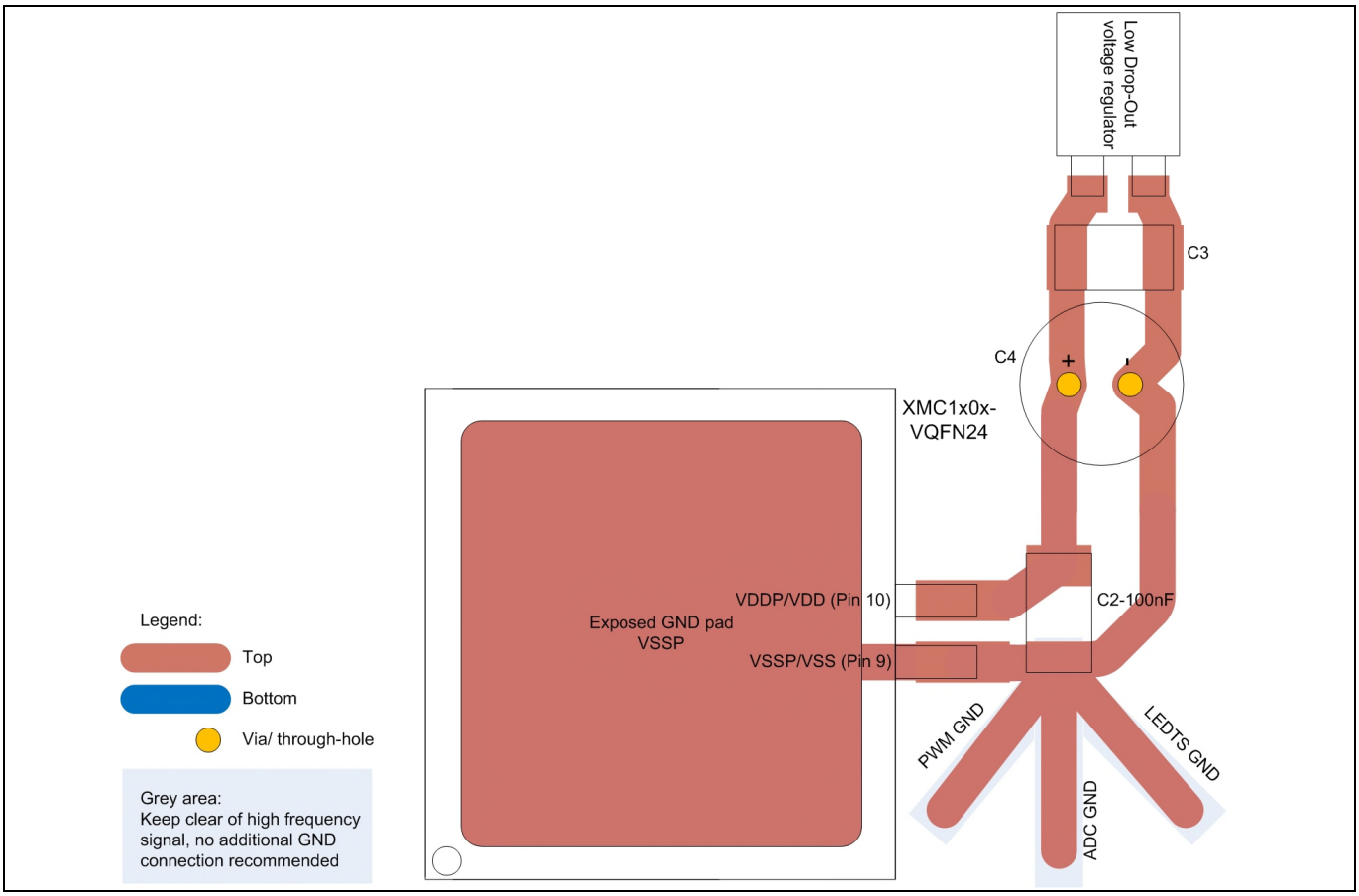

Figure 6 PCB layout for VQFN24 package

For VQFN-24 packages, there is only 1 pair of VDDP / VDD and VSSP / VSS pins, so a star-point ground is recommended at de-coupling capacitor C2.

A star configuration at the VSSP / VSS pin is the least noisy connection for the ADC reference ground. This connection is best coupled to the ADC's reference voltage ground potential and is important for minimizing ADC errors.

From the star point ground, digital grounds (e.g. PWM ground, LED/Touch sense ground) and analog ground (ADC reference ground) are branched out individually to their circuitry.

The noise of the power supply (VDDP / VDD and VSSP / VSS) is filtered by the capacitor C2 in the VQFN24 package.

It must be ensured that the de-coupling capacitors C2 are placed as close to the pins as possible. It is also important to connect the power supply GND and VDD only at those traces shown in the figures. Any additional connection will bypass the de-coupling capacitor C2 and will therefore reduce its effectiveness. The grey areas shown in the figures should be kept clear of any GND connections and GND planes.

The ADC reference GND connection is intended to be used in common mode with the ADC's input pins. Any additional connection to the power supply GND will cause supply noise to be injected to the ADC's reference GND. So, if LED/Touch sense ground is required on the application board, please use the star point ground configuration as shown in Figure 6.

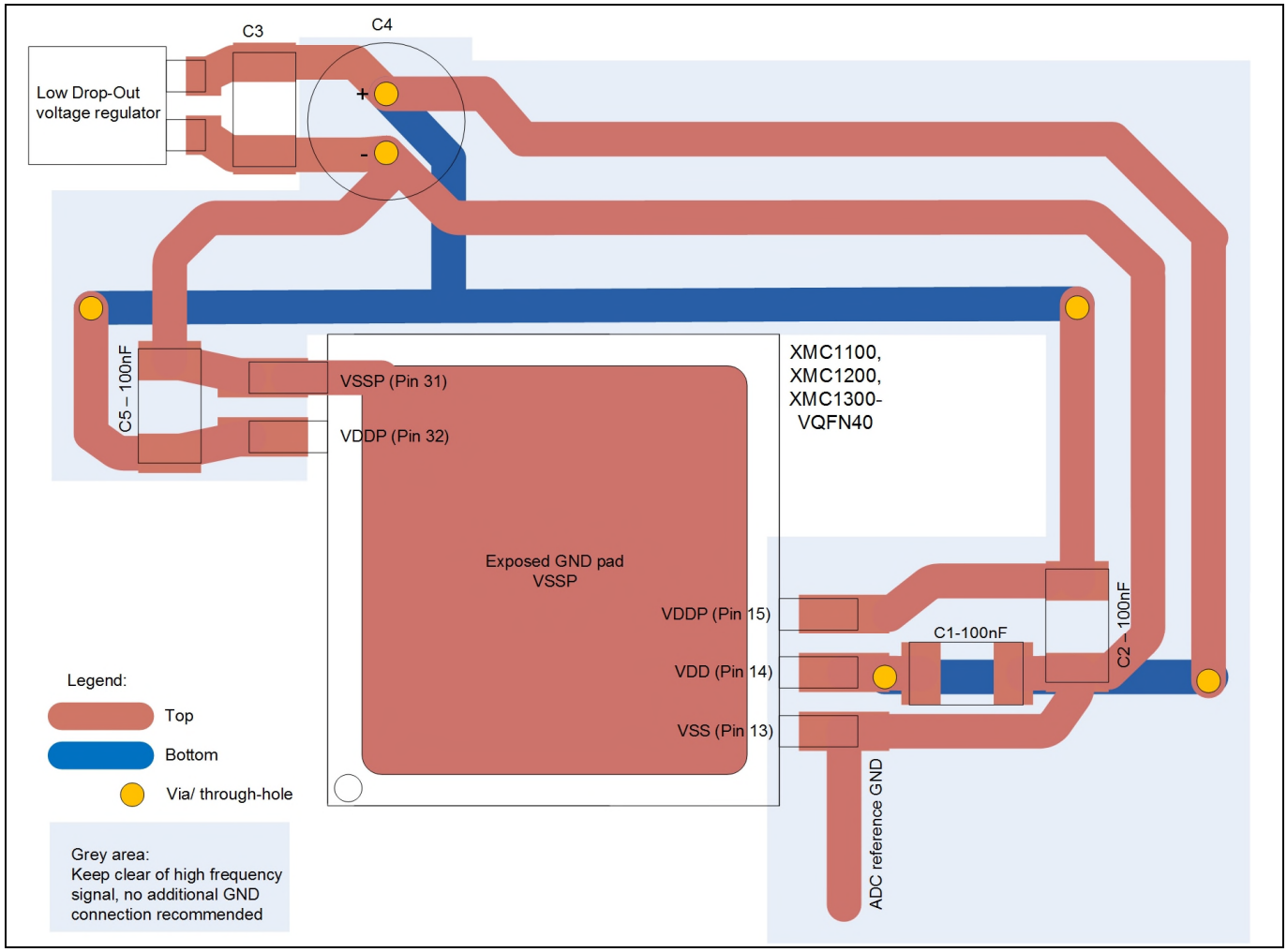

Figure 7 PCB layout for VQFN40 package

With reference to Figure 7, C1 acts as decoupling capacitor for the ADC circuitry. C2 and C5 act as the decoupling capacitors for the digital circuitry of the XMC1000 microcontroller.

The grey areas shown in the figures should be kept clear of any GND connections and GND planes. Ensure that the decoupling capacitors C1, C2 and C5 are placed as close to the pins as possible.

For the VQFN40 package, pin 15 (VDDP) and pin 32 (VDDP) are connected internally. An additional VDDP copper trace will increase the current carrying capability of the internal VDDP bonding wire.

The ADC reference GND connection is intended to be utilized in a common mode with the ADC's input pins. Any additional connection to pin 13 (VSS) in this figure will cause supply noise to be injected to the ADC's reference GND.

3 PCB design recommendation for XMC1400

3.1 Power supply de-coupling, ADC grounding and external oscillator

As mentioned in Chapter 2, de-coupling capacitors are used to buffer the charge needed to feed the required current pulses. Furthermore, noise at the power supply lines might also disturb the microcontroller. This noise can also be filtered by the same de-coupling capacitor.

Analog reference ground pin for ADC should be separate from the noisy digital reference ground for GPIOs.

Although XMC1400 device has internal oscillators DCO1 and DCO2, it also supports main clock and standby clock generation via external oscillators if users prefer. Hence, if a user decided to use an external crystal for clocking, a separate ground island on the GND layer should be provided to reduce the radiation/coupling from the oscillator circuit. This ground island can be connected at one point to the GND layer. This helps to keep the noise generated by the oscillator circuit locally on this separate island. The VQFN40, VQFN48, VQFN64, LQFP64 packages have an exposed die pad which is connected internally to VSSP. This die pad must connect to the board ground. So, at one point of this board ground, it could connect to the separated ground island.

The above are some basic guidelines for the PCB layout of the XMC1400 device. The detailed layout descriptions for different packages are provided in the sections below.

3.2 PCB layouts for VQFN40/48/64 and LQFP64

Normally, there is a low drop-out voltage regulator to step down the input voltage to the operating voltage of the XMC1400 microcontroller. The electrolytic capacitor C4 at the output of the voltage regulator acts as a low pass filter and reduces the ripple voltage of VDDP. C3 is the decoupling capacitor for the filtering of high frequency noise.

At the negative terminal of the electrolytic capacitor C4, a star-point ground should be used. A digital ground trace will run from this star-point ground to VSSP of the XMC1400 microcontroller. Another analog ground trace will also run from the negative terminal of C4 to VSS of the XMC1400 microcontroller. By using this star-point ground configuration, the interference of digital noise at VSSP to the analog ground at VSS is minimized.

3.2.1 PCB layouts for XMC1400-VQFN40

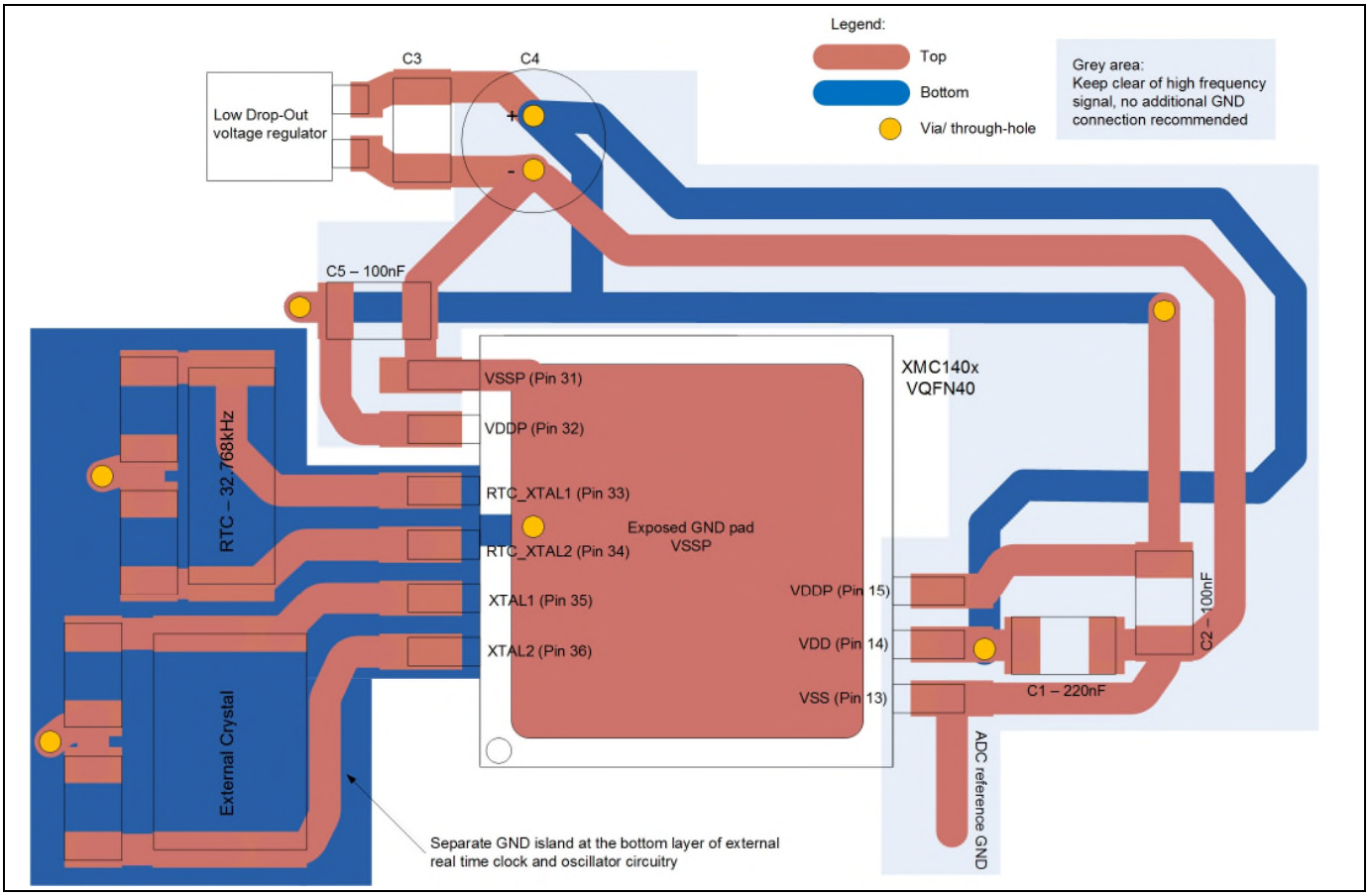

Figure 8 PCB layout for XMC1400 VQFN40 package

C1 acts as a decoupling capacitor for the ADC circuitry. C2 and C5 acts as the decoupling capacitor for the digital circuitry of the XMC1400 microcontroller.

The grey areas shown in the figures should be kept clear of any GND connections and GND planes. Ensure that the decoupling capacitors C1 and C2 are placed as close to the pins as possible.

Note that C1 should be at least 220 nF and C2 and C5 also at least 100 nF. Capacitors with low ESR (ceramic capacitors for example) are recommended.

For the VQFN40 package, pin 15 (VDDP) and pin 32 (VDDP) are connected internally. An additional VDDP copper trace will increase the current carrying capability of the internal VDDP bonding wire.

The ADC reference GND connection is intended to be utilized in a common mode with the ADC's input pins. Any additional connection to pin 13 (VSS) in this figure will cause supply noise to be injected to the ADC's reference GND.

The exposed die pad of VQFN40 packages is connected internally to VSSP. For proper operation, it is mandatory to connect the exposed pad to the board ground. From Figure 8 above, a GND pad (bottom layer) is created under the device's exposed die pad area and the GND pad is connected to VSSP (pin31) of the XMC1400 device. For thermal aspects, please refer to the Package and Reliability chapter of their datasheet.

If the user prefers to use the external oscillator for system clock or real time clock generation, a separate ground island should be created underneath the external oscillator area. This ground island is then connected at one point to the GND layer. As shown in Figure 8, this ground island underneath the oscillator circuitry is connected at one point to the exposed GND pad. This helps to keep the noise generated by the oscillator circuit

constrained locally on this separate island. Traces for the load capacitors and crystals should be as short as possible.

3.2.2 PCB layouts for XMC1400-VQFN48

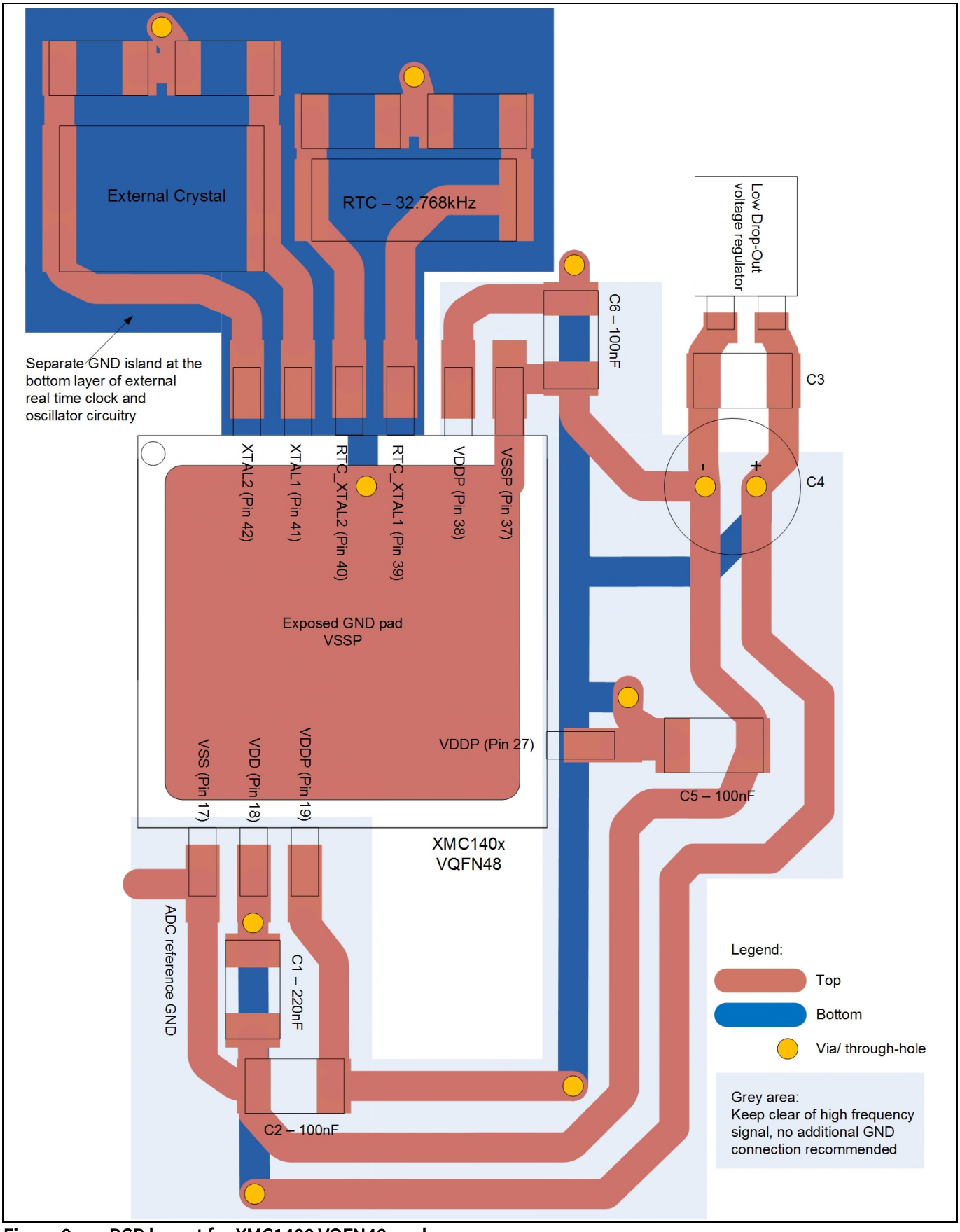

Figure 9 PCB layout for XMC1400 VQFN48 package

C1 acts as a decoupling capacitor for the ADC circuitry. C2, C5 and C6 act as the decoupling capacitors for the digital circuitry of the XMC1400 microcontroller.

The grey areas shown in the figures should be kept clear of any GND connections and GND planes. Ensure that the decoupling capacitors C1, C2, C5 and C6 are placed as close to the pins as possible.

Note that C1 should be at least 220 nF and C2, C5 and C6 also at least 100 nF. Capacitors with low ESR (ceramic capacitors for example) are recommended.

For the VQFN48 package, pin 19 (VDDP), pin 27 (VDDP) and pin 38 (VDDP) are connected internally. An additional VDDP copper trace will increase the current carrying capability of the internal VDDP bonding wire.

The ADC reference GND connection is intended to be utilized in common mode with the ADC's input pins. Any additional connection to pin 17 (VSS) in this figure will cause supply noise to be injected to the ADC's reference GND.

The exposed die pad of VQFN48 packages is connected internally to VSSP. For proper operation, it is mandatory to connect the exposed pad to the board ground. From Figure 9 above, a GND pad (bottom layer) is created under the device's expose die pad area and the GND pad is connected to VSSP (pin37) of the XMC1400 device. For thermal aspects, please refer to the Package and Reliability chapter of their datasheet.

If the user prefers to use the external oscillator for system clock or real time clock generation, a separate ground island should be created underneath the external oscillator area. This ground island is then connected at one point to the GND layer. As shown in Figure 9, this ground island underneath the oscillator circuitry is connected at one point to the exposed GND pad. This helps to keep the noise generated by the oscillator circuit constrained locally on this separate island. Traces for the load capacitors and crystals should be as short as possible.

3.2.3 PCB layouts for XMC1400-VQFN64/LQFP64

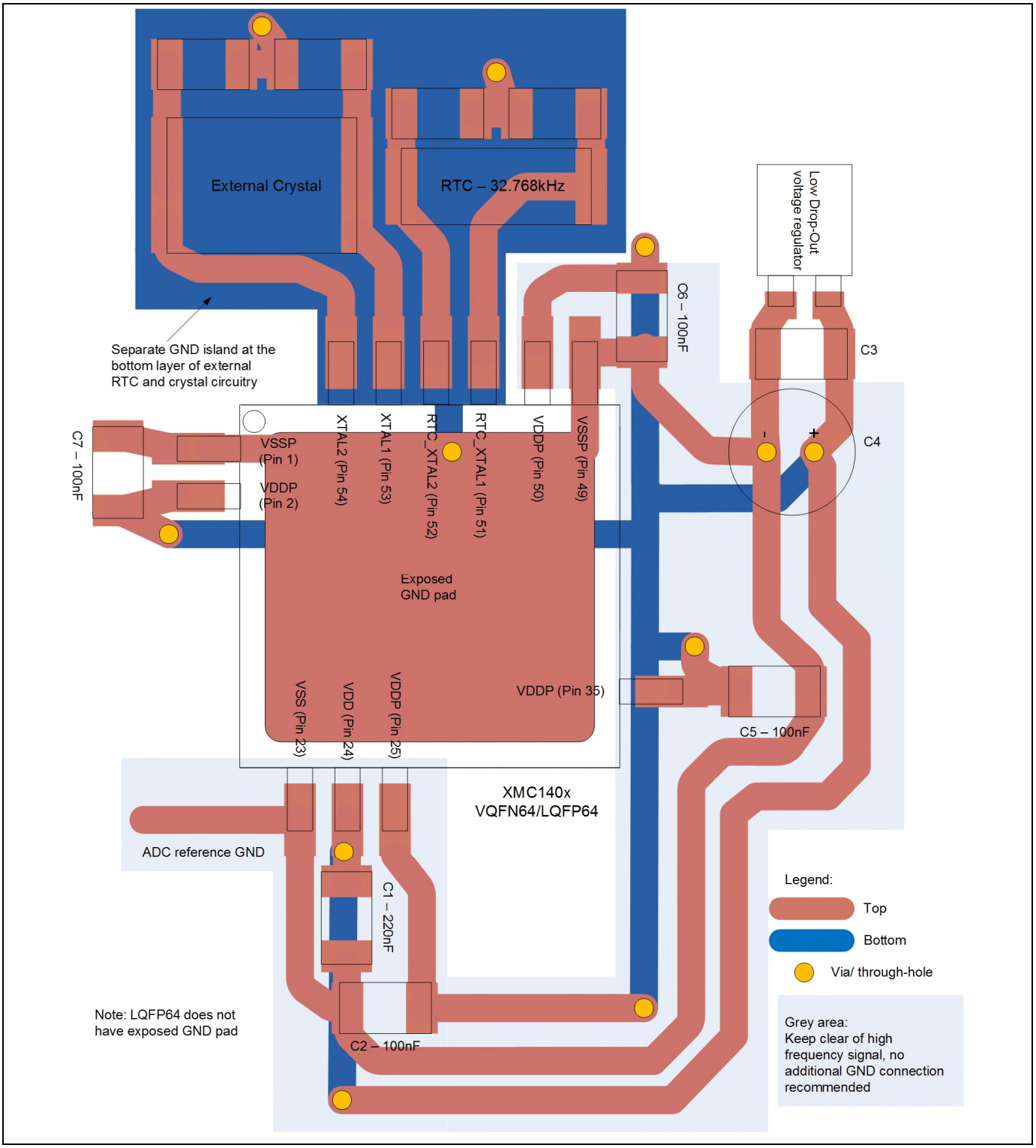

Figure 10 PCB layout for XMC1400 VQFN64 and LQFP64 package

C1 acts as a decoupling capacitor for the ADC circuitry. C2, C5 and C6 act as the decoupling capacitors for the digital circuitry of the XMC1400 microcontroller.

The grey areas shown in the figures should be kept clear of any GND connections and GND planes. Ensure that the decoupling capacitors C1, C2, C5 and C6 are placed as close to the pins as possible.

Note that C1 should be at least 220 nF and C2, C5 and C6 also at least 100 nF. Capacitors with low ESR (ceramic capacitors for example) are recommended.

For the VQFN64/LQFP64 package, pin 25 (VDDP), pin 35 (VDDP) and pin 50 (VDDP) are connected internally. An additional VDDP copper trace will increase the current carrying capability of the internal VDDP bonding wire.

The ADC reference GND connection is intended to be utilized in common mode with the ADC's input pins. Any additional connection to pin 23 (VSS) in this figure will cause supply noise to be injected to the ADC's reference GND.

The exposed die pads of VQFN64 packages are connected internally to VSSP. For proper operation, it is mandatory to connect the exposed pad to the board ground. From Figure 10 above, a GND pad (bottom layer) is created under the device's expose die pad area and the GND pad is connected to VSSP (pin49) of the XMC1400 device. For thermal aspects, please refer to the Package and Reliability chapter of their datasheet. For LQFP64 package, there is no exposed GND pad. However, if a ground plane is provided underneath the LQFP64 package for the VSSP pins, it would help to reduce noise from external crystal and RTC.

If the user prefers to use the external oscillator for system clock or real time clock generation, a separate ground island should be created underneath the external oscillator area. This ground island is then connected at one point to the GND layer. As shown in Figure 10, this ground island underneath the oscillator circuitry is connected at one point to the exposed GND pad. This helps to keep the noise generated by the oscillator circuit constrained locally on this separate island. Traces for the load capacitors and crystals should be as short as possible.

Revision History

Major changes since the last revision

Page or reference	Description of change
V1.0	Initial release
V2.0	Addition of pcb layout for the XMC1400 device
V2.1	Change of document format
V2.2	Changes in Figure 7-10 : Adding power supply to VDD pin

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