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Spec No: 001-89878

Spec Title: WUSB-NX HARDWARE DESIGN GUIDELINES - AN89878

Replaced by: NONE

AN89878

WUSB-NX Hardware Design Guidelines

Author: Sai Prashanth Chinnapalli
Associated Project: N/A
Associated Part Family: CYRF9935
Software Version: N/A
Related Application Notes: For a complete list of the application notes, click here.

AN89878 provides the hardware design guidelines for Cypress WUSB-NX (WirelessUSB™ NX) transceiver. It provides details to create schematics and PCB layouts for a WUSB-NX application. This note also includes a checklist that you can use to confirm design and layout guidelines.

Contents

Introduction

WUSB-NX is a device from Cypress WirelessUSB™ product family. It is a fourth-generation, ultra-low power, 2.4-GHz RF transceiver with a maximum data rate of 2 Mbps. WUSB-NX (CYRF9935) includes a fully integrated receiver, transmitter, frequency synthesizer, and baseband engine.

WUSB-NX applications include the following:

- Wireless mice
- Wireless touch mice
- Wireless keyboards
- Wireless trackpads
- Wireless keyboards with trackpads
- RF remote controls

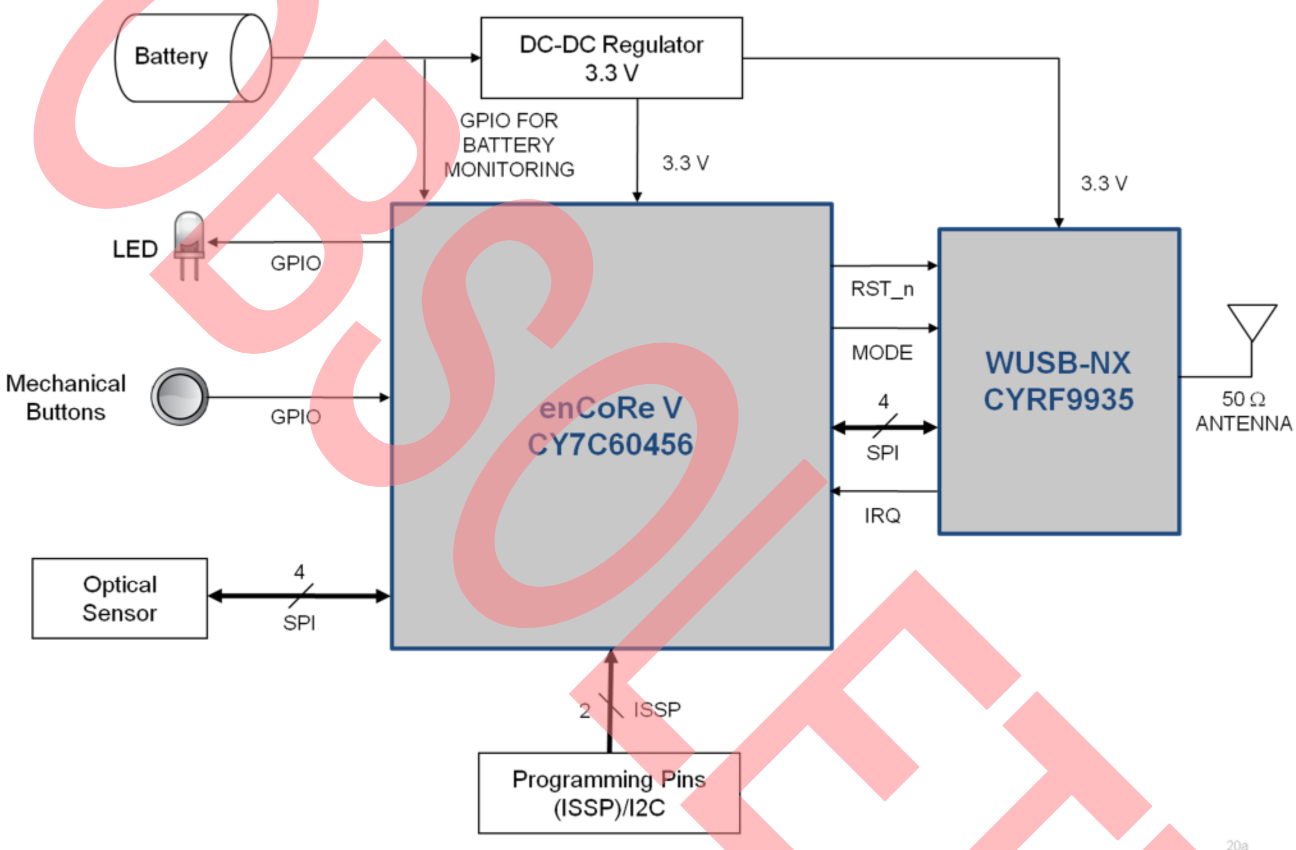
A reference schematic and gerber format are provided along with this application note to illustrate the design of a WUSB-NX module with serial peripheral interface (SPI). The reference schematic for a mouse design is also provided with this application note**.** This application note starts with the schematic design guidelines followed by layout design guidelines. Finally, a design checklist helps validate the PCB design.

Typical WUSB-NX Hardware Design

A WUSB-NX hardware design typically consists of a MCU that can control the WUSB-NX radio using SPI. General interfaces (Buttons, LEDs, I^{2}C, Programming, etc.) can be added to the MCU depending on the application.

Figure 1 illustrates a typical WUSB-NX based hardware design using a Cypress enCoRe MCU.

Figure 1. A Typical WUSB-NX Based Design (Wireless Mouse)



The following sections briefly describe the subsystems that make up the design. The Schematic Design section provides detailed schematics and layout guidelines.

For more information about the capabilities of WUSB-NX, refer to the WUSB-NX datasheet listed in the Reference Documents section.

MCU Interface

WUSB-NX interfaces to an external MCU (CY7C69356, CY8C42XX, CY7C604XX) over SPI. It acts as an SPI slave, driven by the SPI master on the MCU. Other WUSB-NX digital signals (like RST_n, Mode) can be interfaced to the GPIOs of the MCU. The RST_n pin can be used to reset WUSB-NX radio by driving the pin low from the MCU. The Mode pin can be used to enable the WUSB-NX radio to go into receive mode directly without modifying the registers.

2.4 GHz Wireless Capability

WUSB-NX is a RF transceiver that can transmit and receive in the 2.4 GHz ISM band. An antenna, along with a matching network, needs to be connected to WUSB-NX to implement wireless functionality.

Comparison of Cypress's WUSB-LP, WUSB-NL, WUSB-NX

Table 1 lists the differences between WUSB-LP (CYRF6936), WUSB-NL (CYRF8935), and WUSB-NX (CYRF9935). WUSB-LP and WUSB-NL are previous generation radios from Cypress.

Table 1. WUSB-LP, WUSB-NL, WUSB-NX

Parameter	WUSB-LP	WUSB-NL	WUSB-NX
Radio	2.4 GHz with GFSK or DSSS modulation	2.4 GHz with GSFK modulation	2.4 GHz with GSFK modulation
Radio Tx Power	+4 dBm	+1 dBm	+4 dBm
Tx Current Consumption at 0 dBm	26.2 mA	18.5 mA	12 mA
Rx current consumption	21.2 mA	18 mA	15 mA
Max Receive Sensitivity	–97 dBm (125 Kbps)	–87 dBm (1 Mbps)	–93 dBm (250 Kbps)
Data Rate	1 Mbps/ 250 Kbps 125 Kbps	1 Mbps	2 Mbps/ 250 Kbps

Schematic Design

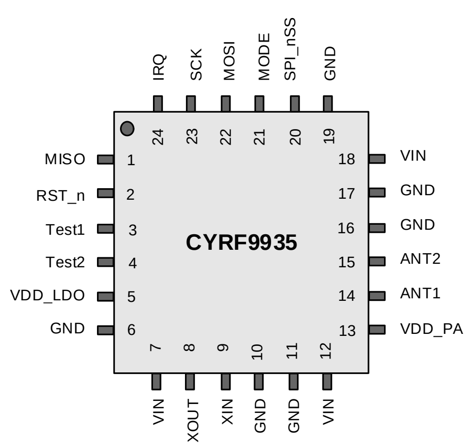
This section gives details about WUSB-NX support circuitry.

WUSB-NX Pinout

WUSB-NX is available in a 24-pin QFN (4×4 mm).

Figure 2 shows the pinout.

Figure 2. 24-Pin QFN WUSB-NX Pinout



Power Supply

The power supply consists of a power source such as AA or AAA batteries and an optional DC-DC regulator.

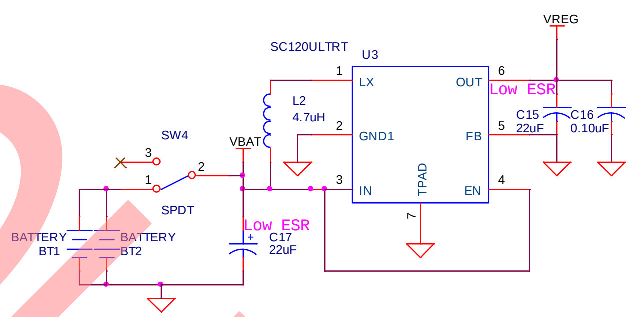
Power Supply Design

WUSB-NX can operate in the voltage range of 1.9 V to 3.6 V. Cypress recommends that you use an external DC-DC regulator for the following types of applications:

- Applications powered by a single AA or AAA battery
- Applications with parts that require a constant supply voltage, such as mouse optical sensors

Figure 3 shows a reference power supply design for WUSB-NX using an external DC-DC regulator SC120ULTRT. VREG of the regulator shall be connected to the VIN of the WUSB-NX to power the radio.

Figure 3. Reference Power Supply Design Schematic



DC-DC Regulator Part Selection Criteria

The DC-DC regulator part must meet the following criteria:

- The output voltage range is 1.9 V to 3.6 V.
- The output noise of the regulator is less than 50 mV pk-pk.

Reference DC-DC Regulator Parts

Two recommended regulators are shown in Table 2.

- **SC120ULTRT:** Semtech SC120ULTRT is a high-efficiency, low-noise, synchronous step-up DC-DC converter that provides boosted voltage levels in handheld applications. The input voltage can vary from 0.7 V to 4.5 V to provide an output voltage of 3.3 V for the system. This regulator can be used for single AA or AAA battery applications.
- **LT1763CS8-3.3:** The Linear Technology LT1763 is a low-noise, low-dropout regulator (LDO) capable of supplying 500 mA of output current with a dropout voltage of 300 mV. The maximum current that the WUSB-NX radio consumes is 12 mA during the transmit stage. This regulator can drive much higher current than required current. LT1763 parts are available in an 8-pin package. Because these parts can support input voltages of 3.7 V to 20 V, they can be used in designs where an AC-DC adapter or lithium-ion batteries are used as a

power source. This regulator cannot be used for single AA or AAA battery applications.

Table 2: Reference DC-DC Regulator Parts

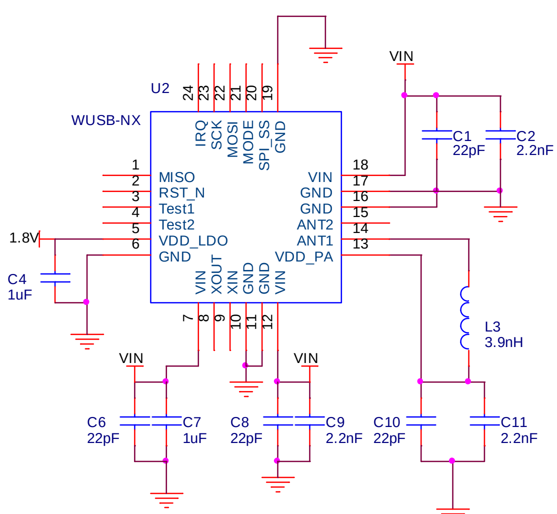
Regulator Part Number and Manufacturer	Type	VBAT (V)	VREG (V)	Remark
SC120ULTRT (Semtech Corporation)	Step-Up DC-DC Regulator	0.7–3.8	3.3	Recommended for single AA or AAA battery applications like wireless mouse and keyboard
LT1763CS8-3.3 (Linear Technology)	LDO Regulator	3.7–20	3.3	Recommended for 9-V battery applications like radio controlled hobby vehicle and toys

Power Supply Connectivity

Three VIN pins of the WUSB-NX are the power input sources for the radio. VIN supports the operating voltage that can vary from 1.9 V to 3.6 V. Each VIN pin should be derived from the common supply and separately decoupled. WUSB-NX has a built-in LDO providing a constant output of 1.8 V (VDD_OUT), which powers the internal blocks of the radio. This pin needs to be decoupled with the capacitor (C4) and should not to be used to power external circuitry. The capacitor is required to reduce the power noise. VDD_PA pin provides power to the antenna from the internal regulator of the device. VREG of the DC-DC regulator is connected to VIN of the WUSB-NX.

Figure 4 shows the connectivity among the VIN, VDD_LDO, and VDD_PA pins.

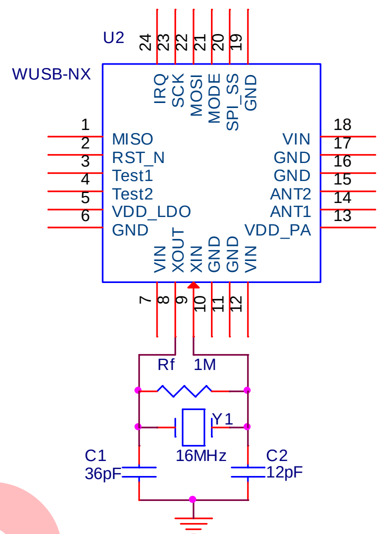
Figure 4. WUSB-NX Power Supply Connectivity



Crystal Requirements

WUSB-NX requires an external crystal. Figure 5 shows the reference schematic for the clock circuit.

Figure 5. Clock Circuit Design



The crystal must meet the following criteria:

- Fundamental mode, parallel resonant 16.000 MHz
- Frequency tolerance of ±60 ppm. This tolerance must be calculated by using the RSS (root square sum) approach involving the following four types of errors represented in parts per million:
  - Base, or initial error, measured at room temperature (I_{ppm})
  - Drift due to temperature changes within the operating temperature range of 0 ºC to 70 ºC (T_{ppm})
  - Drift attributed to aging (A_{ppm})
  - Uncertainty caused by load capacitance error (L_{ppm})

Apply the following formula to calculate the total frequency tolerance using the RSS approach:

Equation 1:

$$Frequency\ Tolerance = \sqrt{I_{ppm}{}^2 + T_{ppm}{}^2 + A_{ppm}{}^2 + L_{ppm}{}^2}$$

- 36-pF and 12-pF capacitances are preferred on each of the nodes of crystal (C1 and C2 respectively in Figure 5).

Reference Crystal Parts

Table 3 shows a list of recommended crystals.

Table 3. Recommended Crystals

MPN	Manufacturer	Stability	Load Cap.
AT-16.000MAGE-T	TXC Corp	30 ppm	12 pF
TSX-3225 16.0000MF09Z-AC3	EPSON	10 ppm	12 pF

Calculating Load Capacitance Values

Load capacitors play a critical role in providing an accurate clock source to WUSB-NX, which determines RF signal accuracy. These capacitors must be chosen carefully based on the load capacitance value of the crystal. This section explains the procedure to choose the correct load capacitor values.

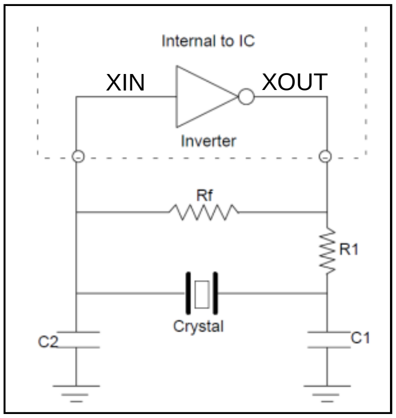
Figure 6 illustrates the crystal circuit. To provide the most accurate clock source, crystal manufacturers specify the optimum load capacitance for the circuit. The two capacitors (C1 and C2) determine the load capacitance, and the net load capacitance is calculated using the following equation:

Equation2:

$$C_L = \frac{C_1 * C_2}{C_1 + C_2} + C_S$$

Cs is the stray capacitance of the PCB, whose typical value is 2.5 pF. Hence, the values of C1 and C2 must be chosen in such a way that they match the crystal's specification. For example, if 10 pF is the load capacitance of the crystal, then the tuning capacitor value would be 15 pF for both C1 and C2. The stray capacitance of the board is assumed to be 2.5 pF which is good assumption. In general, the smaller the value of series resistor R1 (Figure 6), the faster the oscillator will start. R1 must be large enough to avoid overdriving the crystal; yet small enough to provide enough current to start oscillation quickly (an R1 that's too large could cause the oscillator to fail to start). R1 can in some cases be zero (shorted), especially with high-frequency crystals. Rf (Figure 6) is known as feedback resistance, is used to bias the input of the inverting amplifier. By pulling the input of the amplifier toward the voltage at the output, an unstable condition is created, stimulating oscillation. It can also be observed that feedback resistance affects the loop gain of the amplifier, which is augmented as the value for the feedback resistance is increased. In general, lower-frequency crystals require higher values for Rf because their impedance is normally higher than that of high-frequency crystals. Rf for the WUSB-NX radio is 1 MΩ and R1 is 0 Ω.

Figure 6. Crystal Circuit



MCU and RF Connectivity

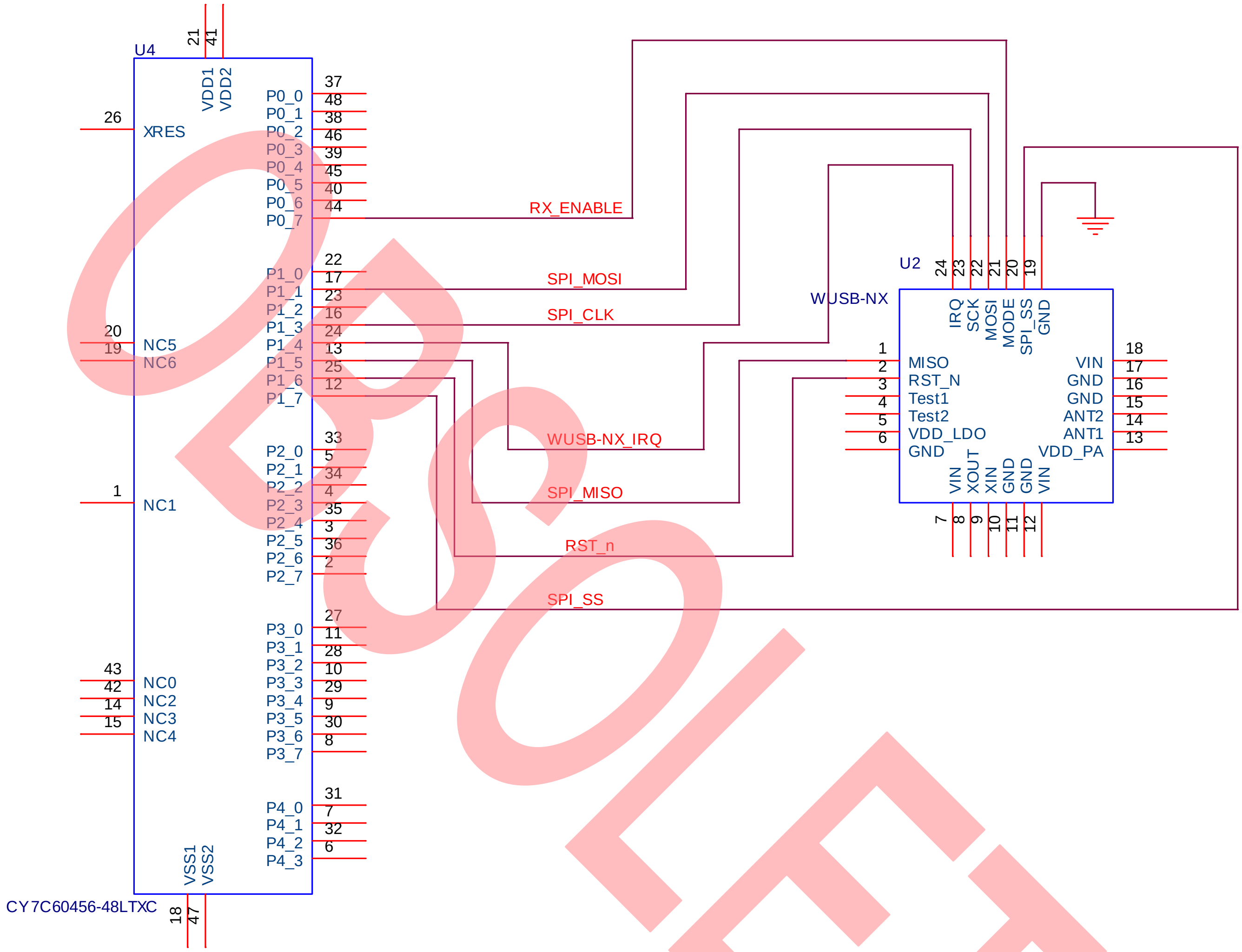
The external MCU interfaces with WUSB-NX over SPI. When using the enCoRe V (CY7C60456) MCU, the following connections are to be made:

- Connect MOSI (Pin22) of WUSB-NX to Pin17 of enCoRe V
- Connect MISO (Pin1) of WUSB-NX to Pin13 of enCoRe V
- Connect SCK (Pin23) of WUSB-NX to Pin16 of enCoRe V
- SPI_SS can be connected to any GPIO (for example Pin12)
- Connect MODE to any GPIO pin. The WUSB-NX Mode pin can be used in the firmware for a smart receive mechanism.

Figure 7 shows the connectivity between the enCoRe V MCU and WUSB-NX blocks. It's a good idea to add test points on the interface signal lines (SPI, Mode, IRQ, RST_n) to help debugging during firmware development.

For other MCUs, refer to the respective MCU datasheet for their SPI port I/Os.

Figure 7. MCU and RF Connectivity



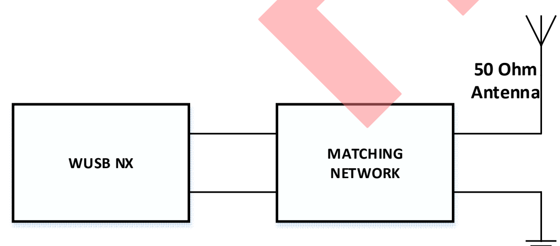
2.4 GHz RF Design

This section explains the radio interface to the antenna.

2.4 GHz RF Design Overview

WUSB-NX is a RF transceiver that can provide up to 2 Mbps data throughput. It supports a differential RF input/out using ANT1 and ANT2 pins. These pins must be connected to a matching network to provide 50-Ω impedance matching for WUSB-NX and the antenna as shown in Figure 8.

Figure 8. WUSB-NX RF Design Overview



Impedance-Matching Circuit Design

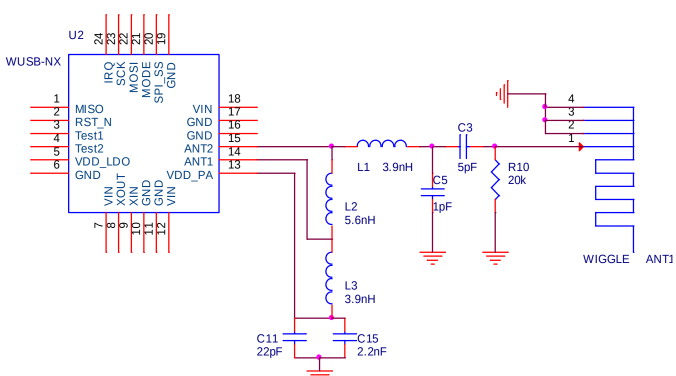
Two capacitors and three inductors form the matching network, which matches the impedances between WUSB-NX and the antenna. The values shown in Table 4 must not be modified. When you select these components, choose parts that have a low power loss. The chosen parts should exhibit a minimum Q of approximately 20 or better, at 2.4 GHz. Table 4 provides recommended part numbers for the matching network.

Table 4. Matching Network Passives

Type	MPN	Manufacturer	Values
Inductor (L1)	LQG18HN3N9S00D	Emerson Network	3.9 nH
Inductor (L3)	LQG18HN3N9S00D	Emerson Network	3.9 nH
Inductor (L2)	LQG18HN5N6S00D	Murata Electronics	5.6 nH
Resistor (R10)	ERJ-3EKF2002V	Panasonic Electronic	20 k
Capacitor (C5)	CC0603CRNPO9BN 1R0	Yageo	1 pF
Capacitor (C3)	C1608C0G1H050C0 80AA	TDK Corporation	5 pF

The differential antenna input/output (ANT2) pin should have a resistance to ground of 51 Ω ± 20 percent to match its 50 Ω impedance which is set by the matching network. In addition, the ANT1 pin requires a DC path to ground. A resistor of 20 kΩ ± 20 percent to ground must be placed on the antenna-side end of the matching network, as shown in Figure 9, if the selected antenna does not have a return path to ground.

Figure 9. Matching Network Design



Layout Design

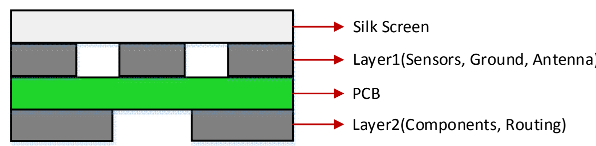
The following sections discuss the layout guidelines for creating WUSB-NX based hardware designs.

PCB Layer Stackup

WUSB-NX based hardware can be designed on a two-layer PCB design. Follow these guidelines to attain optimum RF performance.

Figure 10 illustrate the layer stackup for a two-layer design

Figure 10. Two-Layer Stackup



FR4-based PCB designs perform well with board thicknesses ranging from 0.020 inches (0.5 mm) to 0.063 inches (1.6 mm).

WUSB-NX Device Package Dimensions

The 24-pin device is available in a QFN package. Table 5 lists the package size and recommended pad size:

Table 5. WUSB-NX Package Details

	24 Pin QFN
Package Size	4 mm × 4 mm
Recommended Pad Size	0.25 mm

Power Supply

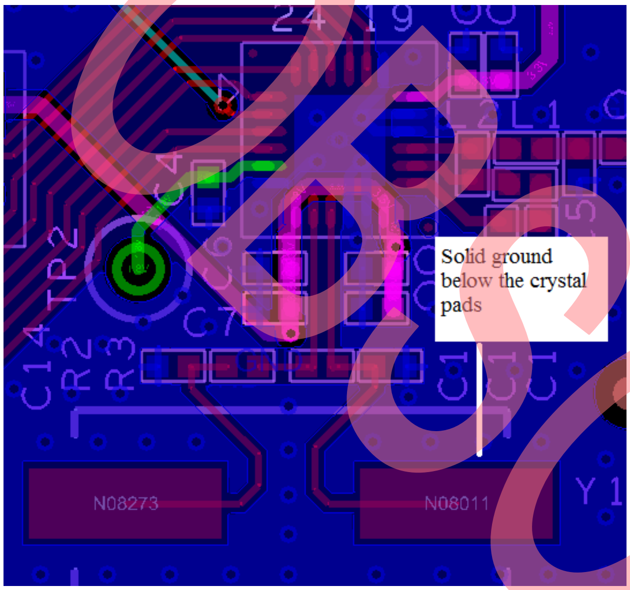
Power Supply Design

- Place decoupling capacitors as close as possible to WUSB-NX.
- Do not gang the decoupling capacitors. Instead, connect them individually to the corresponding power terminals.

Clock

- Do not route any trace beneath the crystal pads or traces connecting the crystal and other components to XIN and XOUT. The layer beneath the crystal pads and these traces must have solid ground, as shown in Figure 11.
- Place the crystal as close as possible to WUSB-NX.

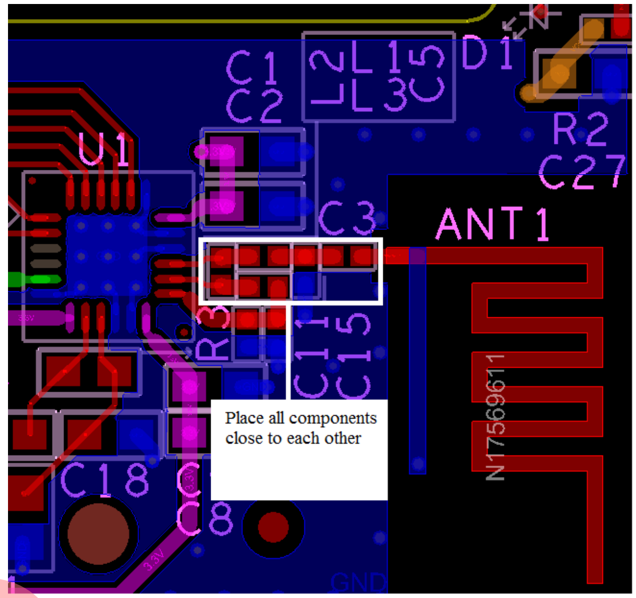
Figure 11. Crystal Layout Design



2.4 GHz RF Design

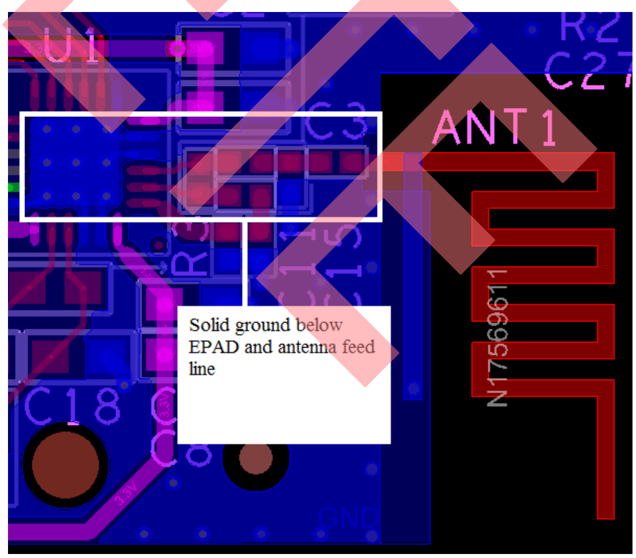
- WUSB-NX supports different types of antenna designs. Refer to the Antenna Recommendations section for the list of antenna designs. This application note also provides the PIFA Antenna Dimensions. Select an antenna design that suits your application. The guidelines provided in this document are based on the PIFA antenna, but they also apply to other antenna too.
- Place the antenna matching network passives as shown in Figure 12.
- Use vias to implement ground stitching between the top and bottom layers underneath the WUSB-NX EPAD.

Figure 12. Antenna Matching Network



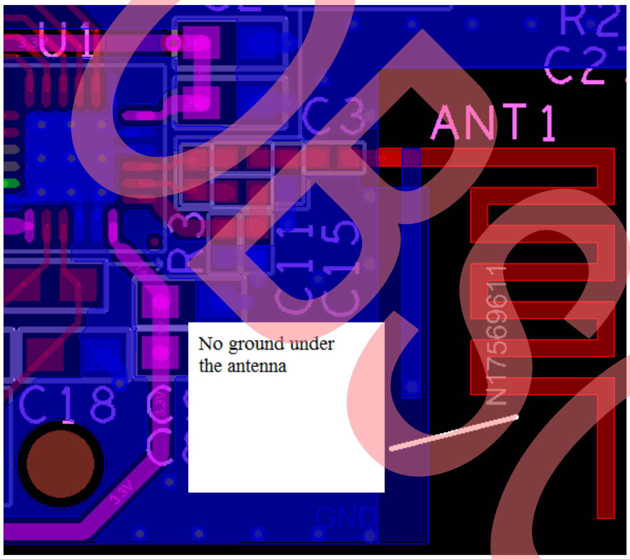
- Maximize ground in the complete design. Ensure that all grounds in the system are tied together.
- Ensure that the layer beneath the WUSB-NX EPAD is solid ground and that it is extended out to the antenna feed line, as shown in Figure 13. Note that the ground regions are colored in blue.
- Ensure that the top layer on which WUSB-NX is mounted has a solid ground pad that aligns with the WUSB-NX EPAD and this pad is soldered to the EPAD. In addition, connect the ground pad on the top layer to the ground pad located on the layer beneath using thermal vias.

Figure 13. Ground Below EPAD and Antenna Feed Line



- Do not route any I/Os near the ANT1 and ANT2 parallel to the ANT1 and ANT2 lines.
- Connect all grounds on the hardware together.
- Isolate the antenna from other layers, and do not add any signal traces or ground to any of the layers beneath the antenna, as shown in Figure 14.

Figure 14. Isolation of Antenna



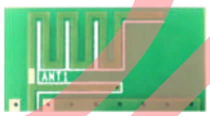
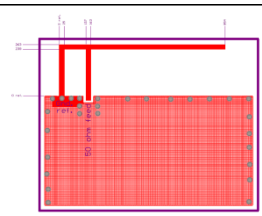
- During PCB manufacturing, do not place metal content such as a PCB vendor logo, Pb-free symbol, or manufacturing lot number under the antenna, because any metal under the antenna can affect the RF radio range. Ensure that this is mentioned explicitly in the fabrication notes of layout design files.

Antenna Recommendations

The antenna is usually the most important factor in achieving a successful RF performance. A rigorous antenna tutorial is beyond the scope of this application note, but here are some simple antenna recommendations that you can apply to WUSB-NX based applications.

You can use virtually any type of good-quality 50-Ω, 2.4 GHz antenna with WUSB-NX. Table 6 lists several available choices.

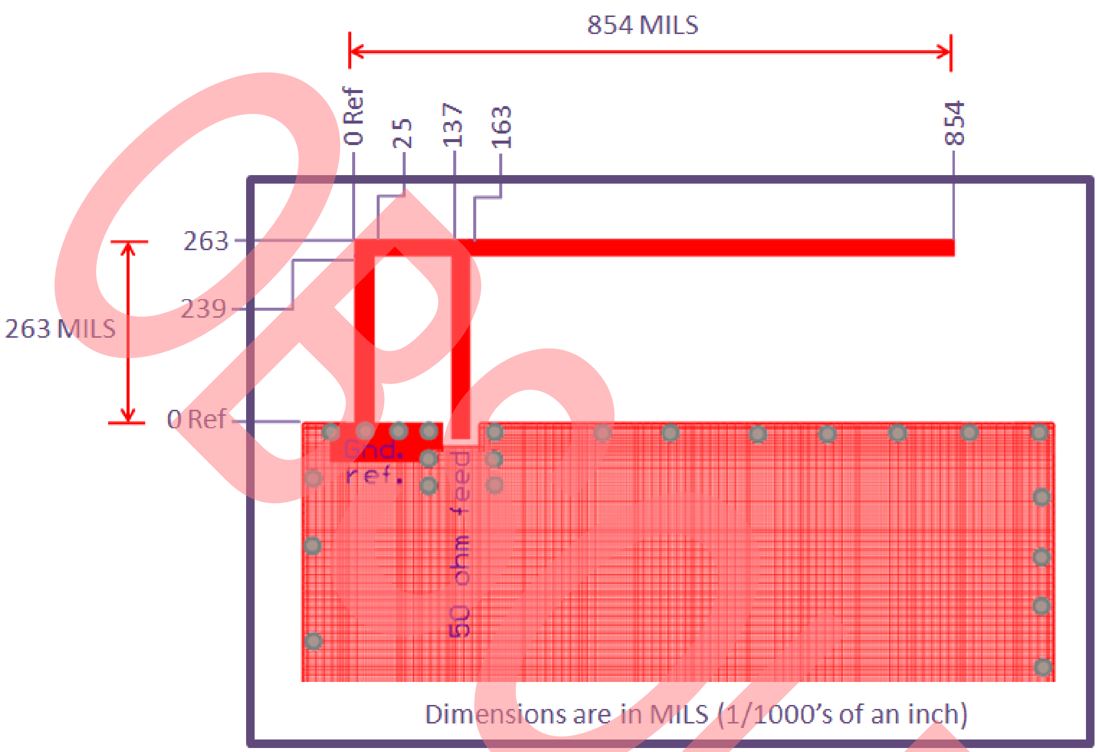
Table 6. Antenna Choices

Antenna Type	Picture or Drawing	PCB Size(mm)	Applications used	Description/Notes
Wiggle antenna		10 X 10 X 0.1	Wireless keyboard, Wireless mouse, Wireless remote controls, Wireless dongles	Described in the Cypress application note AN48610 – Design and Layout Guidelines for Matching Network and Antenna for WirelessUSB™ LP Family Cost: Almost free when added to the existing PCB
Custom printed-trace antenna	This is a specialized antenna, customized to each application.	Depends on the design	Wireless keyboard, Wireless mouse, Wireless remote controls, Wireless dongles	Cost: Almost free when added to the existing PCB
Chip antenna	 Model 2450AT18B100E, Johanson Technology, Inc.	3.2 × 1.6 × 1.3	Wearable devices, sensor tags, Wireless dongles	Easy to use. Read the datasheet and follow all the manufacturer instructions. The manufacturer's specifications for mounting and layout must be exactly followed Cost: Can be expensive
PIFA		22 × 7 × 0.1	Wireless keyboard, Wireless mouse, Wireless remote controls	The printed inverted F-antenna (PIFA) Cost: Almost free when added to the existing PCB
1/2 wave end-fed dipole	 Illustrated: Model W1010, by Pulse.	Length : 109.3 Diameter:10	Radio controlled hobby vehicle and toys	Delivers "textbook" 0-dBm performance Offers easy removal and replacement Accommodates EMC compliance and end applications Requires RF connect on the board Cost: Relatively expensive

PIFA Antenna Dimensions

Figure 15 shows the detailed dimensions of the PIFA antenna for use in WUSB-NX designs.

Figure 15. PIFA Antenna Dimensions



Schematics and Layout Review Checklist

Table 7 is a checklist for all the important guidelines. Provide an answer to each checklist item to find out the extent to which your hardware design meets these guidelines. The answer “Yes” is considered as you are meeting the design requirement.

Table 7. Schematics and Layout Review Checklist

S.No	Checklist Item	Answer (Yes/No)
1	Are all three VIN pins connected together to the same source?	
2	Is connectivity between the MCU and WUSB-NX blocks established over SPI?	
3	Are test points added on the SPI lines connecting the MCU and WUSB-NX blocks?	
4	Does the power supply design ensure that battery leakage does not occur under a low battery condition?	
5	Is the antenna laid out exactly according to the dimensions?	
6	Is it ensured that there is no ground/trace running below the PIFA antenna?	
7	Is adequate solid ground added below the ANT1, ANT2 pins and antenna feed line?	
8	Are decoupling capacitors placed close to the power pins?	
9	Is solid ground added below the crystal pads?	
10	Are all the grounds connected together?	
11	Are the mounting pads laid out according to spec (0.25 mm) for the 24-pin QFN package)?	

S.No	Checklist Item	Answer (Yes/No)
12	Are the grounds on each layer interconnected using as many vias as possible?	
13	Is the Vin Ripple less than 50 mV peak-to-peak?	
14	Are there any signal metal deposits near the Antenna?	

Reference Documents

For more information, refer to the following documentation available at www.cypress.com:

- AN48610 – Design and Layout Guidelines for Matching Network and Antenna for WirelessUSB™ LP Family
- AN4004 - Interference Mitigation Challenges and Solutions in the 2.4 to 2.5 GHz ISM Band
- AN5033 - WirelessUSB Dual Antenna Design Layout Guidelines
- AN64285- WirelessUSB NL Low Power Radio Recommended Usage and PCB Layout
- WUSB-NX Datasheet
- Impedance Matching

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**	4370191	CSAI	05/05/2014	New Application Note
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