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AN19219

WirelessUSB™ Crystal Guidelines

Author: Rich Peng

Associated Project: No

Associated Part Family: CYWUSB6934, CYWUSB6935

Software Version: NA

Related Application Notes: None

To get the latest version of this application note, or the associated project file, please visit http://www.cypress.com/go/AN19219.

AN19219 describes how to design a crystal layout and choose the correct crystal for a WirelessUSB™ system. It also describes PCB layout, crystal PPM, load capacitance, and frequency measurements.

Introduction

A properly designed WirelessUSB™ system can easily operate within a 10 m range. Carefully designed WirelessUSB systems can operate beyond this 10 meter range. Many system design parameters will affect the range of your system. One of the most important of these is a properly designed clock source.

Clock

A good stable clock and its frequency are two of the most important parts of a wireless system. If the radios in a wireless system are not operating on the same frequency, they will not be able to talk to one another.

Clock Requirements

WirelessUSB requires a clock frequency of 13 MHz. The output RF frequency ranges from 2.400 GHz to 2.480 GHz in 1 MHz increments (the channels are 1 MHz apart). This output frequency is produced by using the input clock as the frequency reference for a VCO and PLL. The accuracy and stability of the input clock depend on the external crystal circuitry. Table 1 and Table 2 show the crystal requirements for WirelessUSB and WirelessUSB LR, respectively.

Table 1. WirelessUSB Crystal Requirements

Nominal frequency	13 MHz
Operating mode	Fundamental mode
Resonance mode	Parallel resonance
Frequency stability	±50 ppm (total, including stability, temperature, and aging – 5 years)
Series resistance	100 ohms
Load capacitance	10 pF
Trim sensitivity	< 25 ppm/pF
Drive level	100 µW
Temperature range	–10 ° C to 70 °C

Table 2. WirelessUSB LR Crystal Requirements

Nominal frequency	13 MHz
Operating mode	Fundamental mode
Resonance mode	Parallel resonance
Frequency stability	±30 ppm (total, including stability, temperature, and aging – 5 years)
Series resistance	100 ohms
Load capacitance	10 pF
Trim sensitivity	< 25 ppm/pF
Drive level	100 µW
Temperature range	–40 ° C to 85 °C

Clock Frequency

WirelessUSB is designed to run with an input clock frequency of 13 MHz. An input clock running at 5416 Hz off of 13 MHz will produce an output RF that will be off by 1 MHz or one channel. WirelessUSB will operate in system with both radios' input clocks at 13005416 Hz, but its RF frequency will be 1 MHz higher than expected.

Clock Accuracy

As noted in Clock Frequency, WirelessUSB can operate with its input clock at 5416 Hz off of 13 MHz, but if it is trying to talk to another WirelessUSB that has an input clock of 13 MHz, the two radios will not be able to talk because they are on two adjacent channels. Even if the input clocks are 2700 Hz (208 ppm) apart, they are effectively using two different channels. WirelessUSB needs a more accurate input clock to effectively communicate. WirelessUSB needs to be paired with another WirelessUSB that has an input clock within ±50 ppm of its own frequency for effective communication. A system using WirelessUSB will operate with higher ppm difference, but performance will decrease in both range and interference immunity.

PPM

PPM is the abbreviation for "parts per million," a method of calculation used to specify the permissible frequency deviation of a crystal or oscillator. One ppm on a 13 MHz clock is 13 Hz, and 10 ppm is 130 Hz.

Total ppm clock accuracy is the sum of base ppm, temperature ppm, aging ppm, and trim sensitivity. Total ppm for a WirelessUSB system should be less than ±50 ppm.

Base PPM

The base ppm of the crystal being used is also known as the frequency tolerance. Frequency tolerance is the allowable deviation from nominal frequency. Tolerance is usually specified in ± ppm, at +25 °C and a specific load capacitance. Typical tolerances are from ±10 to 50 ppm.

Temperature PPM

Temperature PPM is also known as frequency stability. Frequency stability is the allowable deviation, in ppm, over a specified temperature range. Deviation is referenced to the measured frequency at +25 °C. Typical frequency stability numbers range from ±10 to 30 ppm.

Temperature ppm can be de-rated by de-rating the temperature range of the product.

Aging PPM

Aging is the change in the frequency of a quartz crystal unit with the passage of time. A typical aging ppm is 2 ppm per year. When you are selecting a crystal, you need to consider how aging ppm will affect product reliability.

Load Capacitance

Load capacitance is the value of capacitance used in conjunction with the crystal unit in a parallel resonant oscillator circuit. In a typical system, the load capacitance of WirelessUSB and PCB layout is 10 pF. Load capacitance of WirelessUSB is typically 7 pF, but can vary 10% from radio to radio. Load capacitance also varies from one layout to the next and depends on signal routing, pad size, and layer stack-up.

Pullability and Trim Sensitivity

Pullability is the change in crystal oscillator frequency due to a change in the load capacitance. This is due to the change in parallel resonant frequency when the load capacitance is changed. Changing the frequency by changing the load capacitance is referred to as "pulling." The frequency can be pulled in a parallel resonant circuit by changing the value of load capacitance. A decrease in load capacitance causes an increase in frequency, and an increase in load capacitance causes a decrease in frequency.

Trim sensitivity is very closely related to pullability. In practical terms, the two are often interchangeable. Trim sensitivity is a measure of the incremental fractional frequency change for an incremental change in the value of load capacitance. Trim sensitivity is expressed in terms of ppm/pF.

Typical trim sensitivities range from 5 to 30 ppm/pF.

Crystal Choice Considerations

The easy choice is to pick a crystal with low total ppm. Crystals with low total ppm can be expensive, so some trade-offs can be made for lower-cost crystals. In a single system, all crystals used with WirelessUSB should be the same type. Crystals of the same type will have similar frequency stability and aging characteristics. Because most systems will be in the same environment (especially HID systems), the temperatures in the system will be similar. Also, all parts of the system will be built at about the same time. Using crystals of the same type will therefore reduce the effects of temperature and aging ppm.

Crystal Tuning

WirelessUSB can be tuned. The load capacitance in the WirelessUSB circuit is adjustable; this will adjust the load resonant frequency of the whole oscillator circuit. One drawback of tuning the oscillator circuit is the additional load capacitance. Too much load capacitance will cause a slow startup time, and should not be used in systems that require fast clock startup time.

Clock Frequency Measurements

The LS radio clock frequency can be measured with a frequency counter on the X13OUT pin. Because this signal is not used in most systems, and the QFN package is difficult to probe, a PCB test point is recommended for this signal. The clock output can be enabled with firmware by writing the clock register in the LS radio. During normal operations this pin should be disabled to remove it as a possible noise source on the PCB and to reduce current consumption.

Crystal Layout

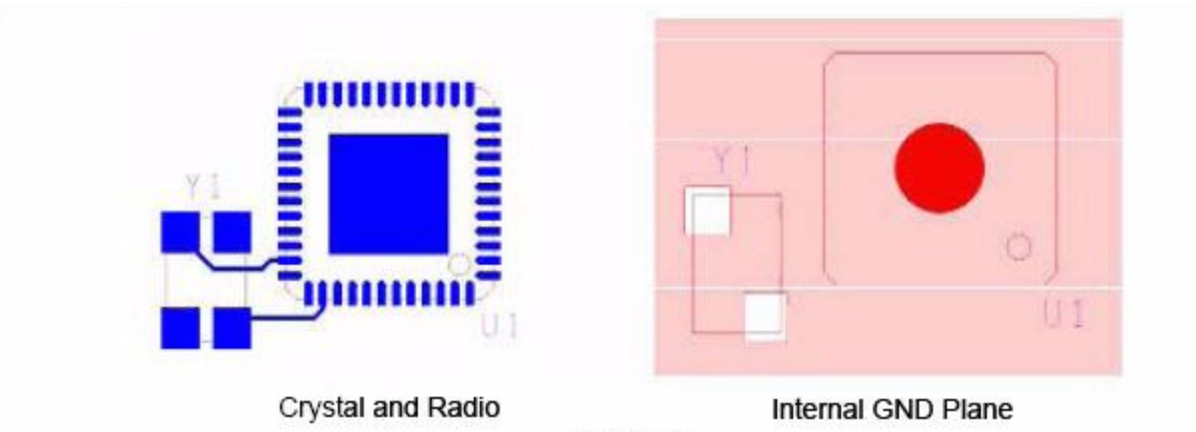
The ideal layout would have the crystal on the same side of the PCB as the radio and placed close to the crystal signal pins of the radio, with identical crystal trace lengths. This placement would keep the crystal trace paths short and reduce parasitic capacitances, which could produce noise in the system. The two crystal traces should have matched length, avoid vias, and have good isolation from noise sources. The WirelessUSB crystal circuit performs best when the crystal traces are closely matched in both lengths and parasitic capacitances.

- Crystal and radio on same side of PCB.
- Crystal placed near crystal pin on the LS radio.
- Crystal trace paths short as possible.
- Match crystal trace path for length and parasitic capacitance.
- Avoid vias on crystal traces.
- Isolate crystal from noise sources.

Crystal layouts should be identical for all radios in the system. By keeping layouts identical, the parasitic capacitance on the crystal traces will be similar for each PCB in the system. Similar parasitic capacitance will produce similar load capacitance, thus reducing the effect of trim sensitivity ppm on each radio of the system.

On multilayer PCBs, one way to reduce parasitic capacitance on the crystal is to void the internal layers directly beneath the crystal pads (see Figure 1). This is highly recommended when systems are composed of PCBs with differing layer counts.

Figure 1. Voiding Internal Layers Beneath Crystal Pads



Summary

You must carefully design the layout and choose the correct crystal for a WirelessUSB system. If you follow the guidelines in this application note, you can easily produce a stable clock source for WirelessUSB system.

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Document History

Document Title: AN19219 - WirelessUSB™ Crystal Guidelines

Document Number: 001-19219

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	1408704	YIS	08/23/2007	New application note.
*A	3170600	LRDK	02/11/2011	Added Abstract. Added Summary. Applied new template.
*B	3355419	ZHC	08/26/2011	No change.
*C	4504619	LIP	09/16/2014	Updated to new template. Completing Sunset Review.
*D	5839346	AESATMP9	07/31/2017	Updated logo and copyright.
*E	5900075	CHYY	09/28/2017	No technical updates. Completing Sunset Review.

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