Introduction to In-band Communication of Qi-based Wireless Power Designs and System-Level Challenges

This application note describes the in-band communications and system-level challenges presented when using Qi-based wireless power designs.

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1. Introduction

In Qi-based wireless power designs, Receiver (Rx) and Transmitter (Tx) exchanges the messages using the bidirectional in-band communication. These messages are critical to establish the power contract, regulate the operating point, and detect foreign objects.

Receiver-to-transmitter communication is completed by Amplitude Shift Keying (ASK) using with a bit-rate of 2Kbps. The receiver modulates the amplitude of the load applied to the receiver's coil by switching the external capacitors (Cmod) from AC1 and AC2 both to ground. To the transmitter, this appears as an impedance change, which results in measurable variations of the transmitter’s coil’s voltage and current. The transmitter’s controller decodes the message using integrated voltage and current demodulator and then regulates the power transfer accordingly.

Transmitter-to-receiver communication is accomplished by frequency-shift keying (FSK) modulation over the power signal frequency using with a bit-rate of 200bps. The receiver detects the minor change in operating frequency and decodes the message sent by the transmitter.

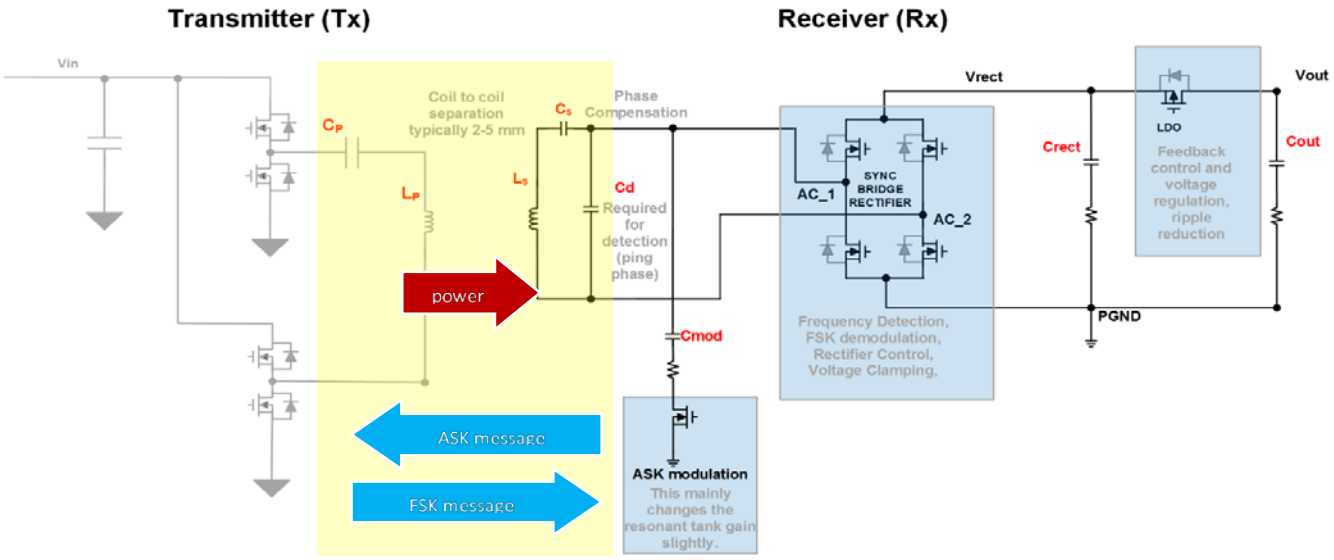


Figure 1: Qi-based Wireless Power System Overview

The ASK byte-encoding scheme, FSK byte-encoding scheme and packet structure comply with the WPC specification. Furthermore, the checksum is used within the messages to assure the integrity of the data being sent.

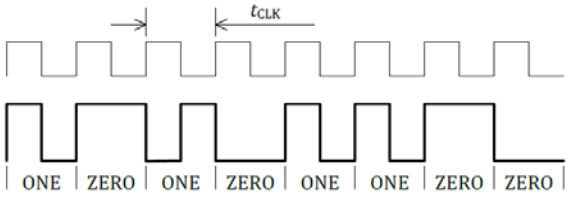


Figure 2: Bit Logic "0" and "1" Defined in the WPC Specification

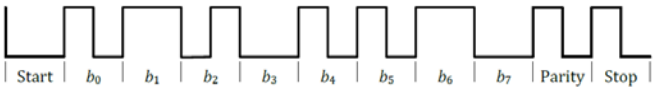


Figure 3: Byte Structure in WPC Specification

Preamble	Header	Message	Checksum

Figure 4: ASK Message Structure in WPC Specification

Header	Message	Checksum

Figure 5: FSK Message Structure in WPC Specification

ASK and FSK messages can be monitored using the scope probe on Receiver Rectifier (Rx_VRECT) node, Transmitter voltage demodulator input (VDEM) and Transmitter current demodulator Input (IDEM). Furthermore, a Qi sniffer can be used to sniff the communication packets between receiver and transmitter.

CH1: Rx VRECT, CH2: Rx VOUT,CH3: Tx VDEM, CH4: Rx IOUT

Figure 6: Typical Waveform

2. System-Level Challenges

In typical wireless power designs, the receiver's main LDO output (VOUT) is connected to the input of a battery charger. The battery charger charges the battery and provides the system current. While the device is charging wirelessly, the output current of wireless power system is equal to the input current of the battery charger. The output current of wireless power receiver can be increased or decreased by changing the DC current limit of the battery charger.

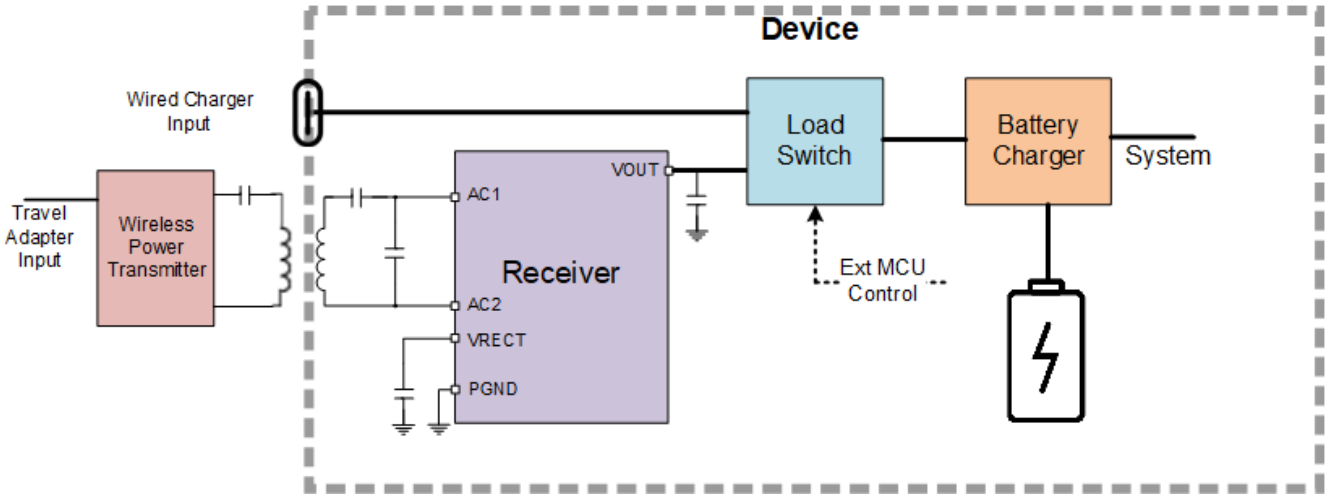


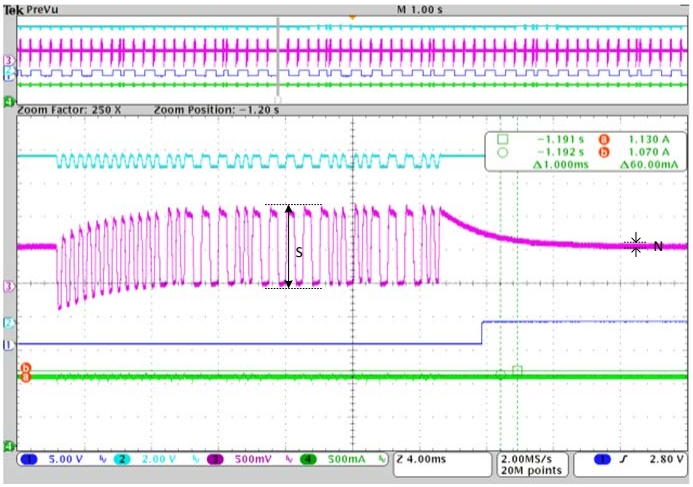
Figure 7: System Diagram

When the battery charger is in Constant Voltage (CV) mode of operation, the battery charging current low and the wireless charging output has a higher impedance. The dynamic system loads on the battery charger's system output causes wide output current swings on the wireless power receiver's output.

3. Design Recommendations

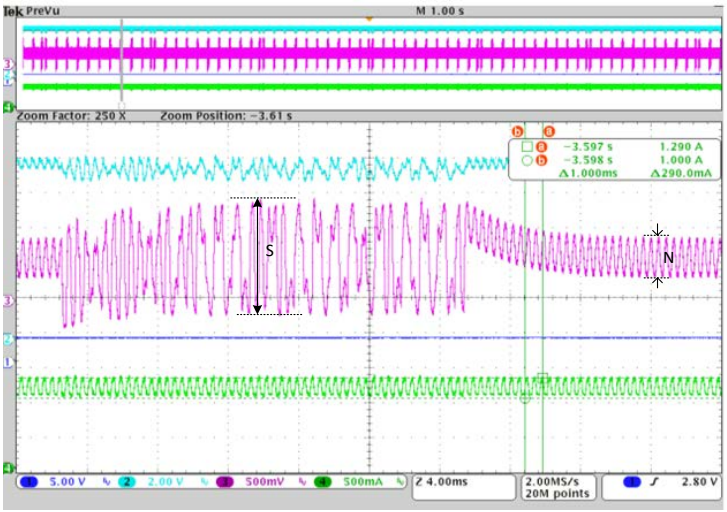
The wireless power receiver uses a bi-phase encoding scheme to modulation data bits onto power signal. For this purpose, the receiver aligns each data bit to a full period clock of an internal clock signal such that the start of a data bit coincides with the rising edge of the clock signal. This internal clock signal has a frequency f_{clk}= $2^{\pm 4}$ kHz based on WPC 1.2.4 spec. The number of bit errors can be potentially high if the wireless power receiver ripple has a frequency that is close to the modulation frequency f_{clk}. Therefore, the system designer needs to consider removing similar modulation frequency (< 8kHz) noise for proper wireless charging communication.

Also, ripple on the wireless power receiver's load yields a ripple on the wireless power transmitter's coil current and voltage which feed into the transmitter's demodulator circuit. As a result, the ripple on the receiver's load current can lead to decoding errors in the transmitter's demodulation circuitry. So, system designers needs to minimize the noise on the receiver's output to maintain a proper signal-to-noise ratio (SNR) on the transmitter's demodulator input for effective decoding. Figure 8 shows an example of a good transmitter demodulation signal without noise signal and a good SNR, which is over 10. The ripple frequency and noise frequency (3kHz) cause a poor demodulation signal with low SNR which results in packet error within the transmitter's demodulator as shown in Figure 9.



CH1 = GP_packet receiving; CH2 = Vrect_Rx;
CH3 = VDEMO_Tx; CH4 = Iload_Rx;

Figure 8: Good Signal-to-Noise Waveforms {SNR = (S-N)/N = (11-1)/1 = 10)}



CH1 = GP_packet receiving; CH2 = Vrect_Rx;
CH3 = VDEMO_Tx; CH4 = Iload_Rx;

Figure 9: Bad Signal-to-Noise Waveforms {SNR = (S-N)/N = (17-6)/6 = 1.6)}

4. Summary

In Qi-based wireless power designs, in-band communication is critical to uphold an excellent user experience. The system noise from the receiver's output can impact the quality of the transmitter's demodulator input. A system designer can measure the SNR ratio at the transmitter's demodulator input to understand the impact of the receiver's output noise. It is recommended for system designers to maintain an SNR ratio of greater than 5 on the Tx demodulator's input for all the receiver's load conditions.

5. Revision History

Revision	Date	Description
1.00	Aug 23, 2021	Initial release.

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