BP66FW1242 Qi Wireless Charger Receiver Application

D/N: AN0578EN

Introduction

Qi is an interconnection standard for short distance and low power wireless inductive power transmission, developed by the Wireless Power Consortium (WPC). Its main purpose is to provide a convenient and universal wireless charging standard for mobile phones and other portable electronic devices. The Qi protocol is divided into transmitter, Tx, and receiver, Rx. The Tx is used for power transmission and data communication while the Rx is responsible for power reception and data communication. Power and communication transmission are both implemented through alternating electromagnetic fields, therefore the Rx should have a rectification and communication modulation function.

A lithium battery is one of the most common types of rechargeable batteries used in portable electronic devices. It features a high energy density without having a memory effect and has a very slow charge loss when not in use. In addition to consumer electronics, more and more advanced lithium-ion batteries are becoming increasingly popular among military, electric vehicles, aerospace and other applications. However, due to the high thermodynamic activity and flammability of lithium, the charging and discharging process must be implemented under certain standards to ensure safety. Incorrect charging or discharging, using inappropriate currents or voltages could cause battery combustion.

Holtek's wireless charging receiver MCU, the BP66FW1242, contains an integrated synchronous full-bridge rectifier function, a linear charging function, an LDO and a communication modulation function. These functions form the circuits required by a wireless charging receiver. The device can communicate with a wireless charging transmitter, Tx, based on the Qi wireless charging standard and carry out linear charging management of lithium batteries for portable devices. This will prevent any dangerous lithium battery overcharging situations from occurring. It is suitable for use in small size wireless charging receiving devices. This document will provide more details about the principles of Qi communication and linear charging as well as their usage.

Functional Description

Qi communication circuitry can be divided into two types, resistance modulation and capacitance modulation. The operating principle is that the Rx changes the power transferred from the Tx and sends data back to it. The Tx can receive data sent by the Rx through a demodulation circuit. Because the Qi wireless charging is based on an LC resonance principle, the closer to the resonance frequency it is the higher the power transfer will be. The Tx can adjust the frequency according to the content of the control signal so as to modify the transmission power to meet the requirements of the Rx. The Qi wireless charging architecture is shown in the following figure.

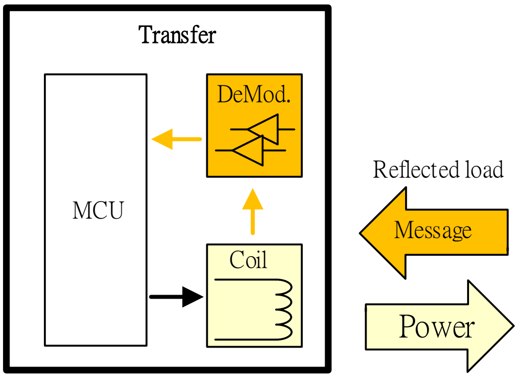

Figure 1. Qi Wireless Charging Principle

The BP66FW1242 includes an integrated linear charging circuit for lithium battery charging as shown in the Figure 2 which can automatically switch between trickle, constant current, constant voltage and recharge modes to ensure safe charging. The complete hardware circuit design does not require additional MCU control thus greatly reducing design complexity. Users only need to read the state of the VCCS and CVS pins to obtain the status of the linear charging circuit, which can be no charging, charging or fully charged.

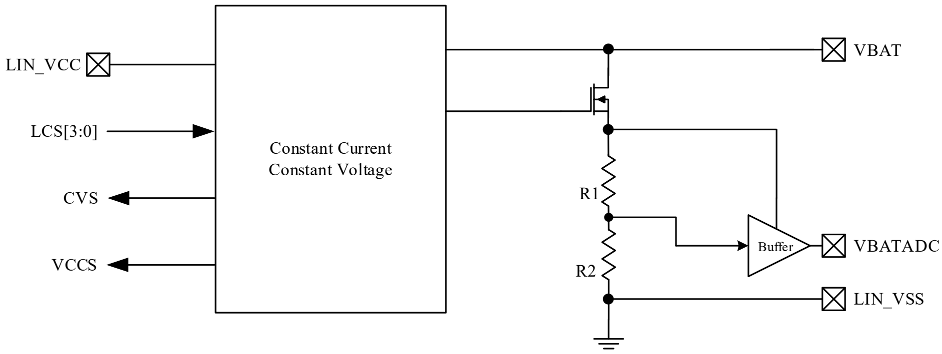

Figure 2. Linear Charging Principle

Operating Principles

1. Qi communication packet format: a single Qi byte format includes 11 bits with each bit being logic "0" for one transition and "1" for two transitions. The width of each bit is 1ms, as shown in the following figure: b0=1, b1=0.

   Byte format:

   - 1-bit start - fixed at ‘0’
   - 8-bit data
   - 1-bit parity – even parity
   - 1-bit stop - fixed at ‘1’

   As shown in the Figure 3.

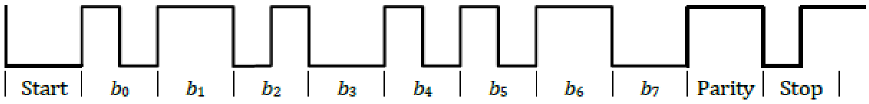

Figure 3. Qi Communication Byte Format

2. Qi complete packet format: Preamble, Header, Message 1, Message 2 and Checksum.

   Complete packet composition:

   - Preamble - 11~25 bits, all = ‘1’
   - Header - 1 byte
   - Message - 1~27 bytes
   - Checksum - 1 byte

   More details are shown below:

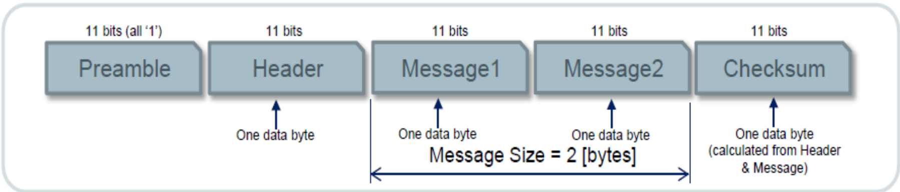

Figure 4. Complete Packet Format

3. Qi communication procedure: Selection Phase, Ping Phase, Identification & Configuration Phase and Power Transfer Phase. The Selection Phase is equivalent to standby. The Ping Phase is used to detect whether an Rx device has been placed above the Tx. The Identification & Configuration Phase is used to synchronize parameters and definitions. The Power Transfer Phase is used for power control and efficiency detection. In each Phase, if an error or protection occurs, the system will return to the Selection Phase.

   According to the Qi protocol, the Tx will ping the Rx every 40ms, which occurs in the Ping Phase.

If the Rx receives the ping signal, it will calculate the signal according to the maximum signal strength (Umax) already set and return the received Signal Strength (0x01, SS). If the Rx has a correct response, it will enter the Identification & Configuration Phase. According to the Qi, the Signal Strength is calculated as follows:

$$\text{Signal Strength Value} = \text{U/Umax} \times 256$$

The Identification (0x71) contains Qi version number, factory code and product ID while the Configuration (0x51) contains power settings, data length and time parameters. After the Rx has finished the signal receiving, it will enter the Power Transfer Phase.

In the Power Transfer Phase, the Rx will transfer the Control Error (0x03, CE) and the Received Power (0x04，RP), which are provided to the Tx for power control and foreign object detection. The Control Error (CE) value is composed of 8-bits of data and is within the range of -128 to +127, which stands for -100% to 100%. The CE value of Qi specification is calculated as follows:

$$\text{CE} = \frac{\text{Power(Target Value)} - \text{Power(Current Value)}}{\text{Power(Current Value)}} \times 128$$

The Received Power value is composed of 8-bits of data and is within the range of 0 to 255, which stands for 0 to 10W. The RP value of the Qi specification is calculated as follows:

$$\text{Received Power Value} = \text{Pre-received Power (Rx Power)} \times 128/(10W/2)$$

The control architecture of the Qi system is shown in the figure below.

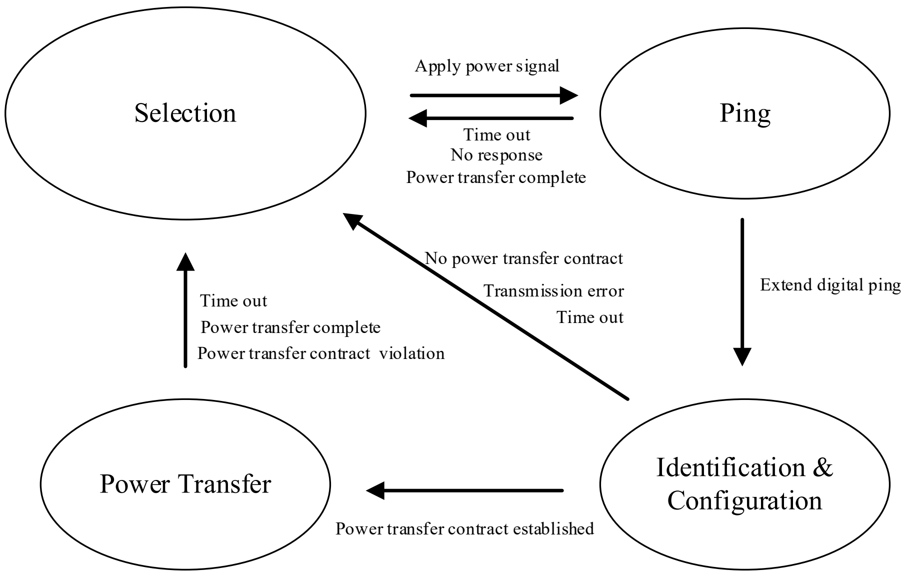

Figure 5. Qi System Control Architecture

Hardware Description

In order to meet the Qi communication requirements, the BP66FW1242 wireless charging receiver provides full hardware resources which contain a synchronous full-bridge rectifier function, a linear charging function, an LDO, an integrated reference voltage and a communication modulation function. In each phase of the Qi, the BP66FW1242 needs to cooperate with external hardware circuits to achieve communication coding, power calculation and other functions. The hardware circuit of the Holtek's BP66FW1242 demo is shown in the following figure.

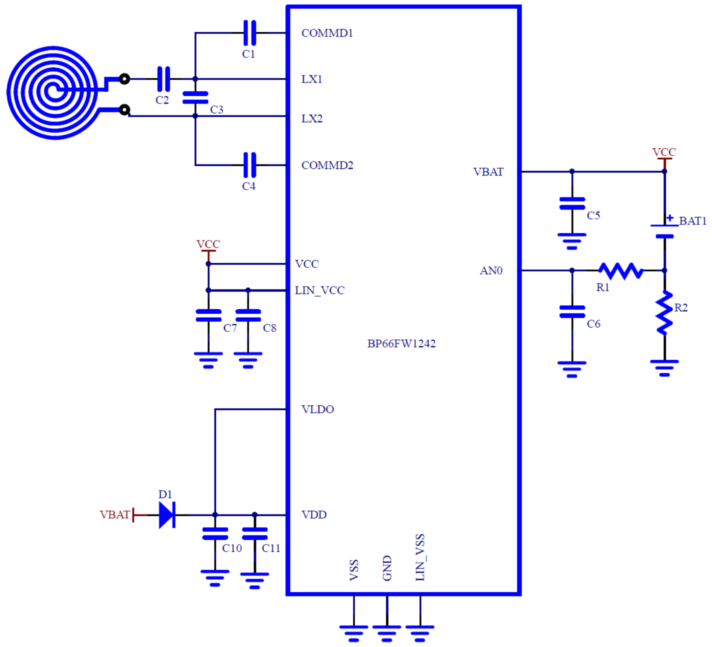

Figure 6. BP66FW1242 Application Circuit

Qi Calculated Method of Communication Data

The BP66FW1242 include an integrated modulation circuit, which controls the resonant frequency through the external capacitor C1 and C4 to generate a modulation signal. The program sends packets defined in different phases according to the Qi protocol. The related packets are described below.

1. Signal Strength Packet - 0x01

   The Signal Strength (SS) value is composed of 8-bits of data and has a range of 0 to 255, which is used to represent the received power during the Ping Phase. The current voltage, V_{CC}, is measured by the internal $V_{CC}/5$ voltage divider circuit and the reference voltage, V_{BG}. This is calculated proportionately with 8V=256. The calculated SS value is returned to the Tx. Then the Tx will continuously transfer power to enter the Identification & Configuration Phase.

$$SS = \left(\frac{\text{A/D Measured Value}}{4096} \times \text{A/D Reference Voltage}\right) \times 5 \times \left(\frac{256}{8V}\right)$$

2. Control Error - 0x03

   The Control Error (CE) value is the tolerance between the current V_{CC} voltage and the target voltage. The CE value lies within a range of -128 to +127, which stands for -100% to 100%. The

MCU calculates the CE value according to the difference between the current voltage and the target voltage. The current voltage, V_{CC}, is measured by the internal $V_{CC}/5$ voltage divider circuit and the reference voltage, V_{BG}. The CE value is calculated and then transferred back to the Tx.

$$CE = \left(\frac{V_{CC}(\text{Target Value})}{\frac{\text{A/D Measured Value}}{4096} \times \frac{A}{D}\text{Reference Voltage} \times 5} - 1 \right) \times 128$$

3. Received Power - 0x04

The Received Power (RP) value is the received power of the Rx and is within a range of 0 to 255. The RP value represents the power of the Rx. The MCU calculates the RP (0x40) value according to the received power. The RP includes the Rx system power consumption and the charging power. The RP value, under different V_{CC} voltages, can be calculated by using the battery charging sampling resistor, R4, and reference voltage, V_{BG}.

$$RP = \frac{\left(\frac{\text{Measured Current Value} \times \text{A/D Reference Voltage}}{4096 \times \text{Current Sampling Resistance Value}} + \text{System Current Consumption}\right) \times \frac{\text{A/D Measured Value} \times \text{A/D Reference Voltage}}{4096} \times 5}{5W} \times 128$$

Linear Charger

The BP66FW1242 is designed with a linear charger function dedicated for lithium battery mobile products. There are three charging modes for the linear charger, which are the trickle mode, constant current charging mode and constant voltage charging mode. If the lithium battery is improperly charged, it can be damaged and in extreme cases could catch fire or explode. With different charging mode control, the linear charger function provides functions for charging status read, such as abnormal input voltage, charging, full-charged battery, etc. The trickle mode, constant current charging mode and constant voltage charging mode are described below and the flowchart is shown in Figure 7.

- Trickle Mode: This mode is used for completely discharged batteries or the battery voltage is less than 3V. This mode is the first stage of charging. When the voltage is less than 2.5V, the battery will undergo a pre-charge using a typical constant current value of 8.3mA. When the voltage is greater than 2.5V, the battery will undergo a pre-charge using a typical constant current value of $1/12 \times I_{BAT\_CC}$.
- Constant Current Charging Mode: When the battery voltage is equal to or larger than 3V and less than 4.2V, the charging current will then switch to a typical constant current during this second stage. The charging current is determined by the LCS[3:0] bits and is within the range of 100mA to 1000mA.
- Constant Voltage Charging Mode: Once the battery voltage has reached 4.2V, it will be charged using a constant voltage during this third stage. The charging voltage should be fixed at 4.2V with a tolerance to within 1%. The charging current gradually decreases as the constant voltage charging time increases. Typically, the constant voltage charging stage is completed when the charging current reduces to a value less than $1/12 \times I_{BAT\_CC}$. At this moment, the battery is be fully charge and stop charging, the CVS bit will be set to 1.After being fully charged, the battery

will be continually monitored. When the battery voltage is equal to or less than 4.0V, the battery will be recharged and enter the next charging cycle.

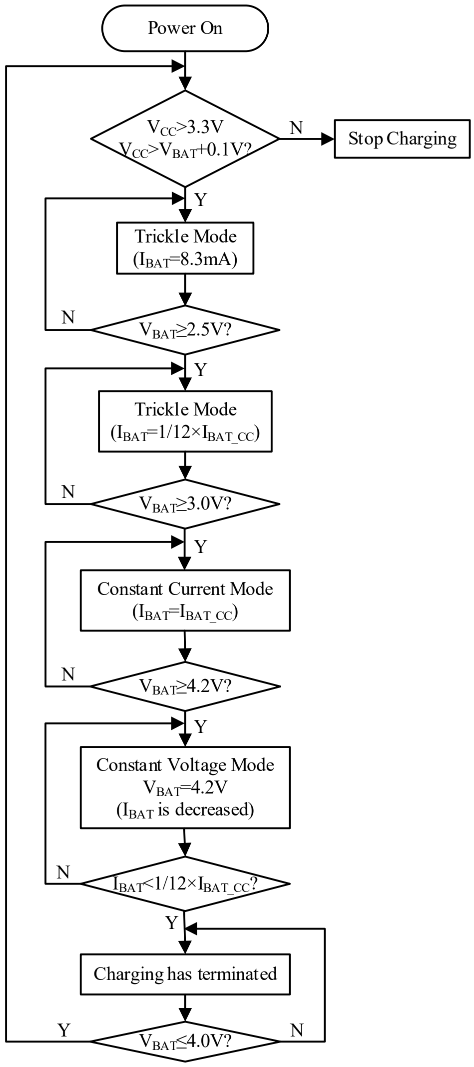

Figure 7. Linear Charger Flowchart

Linear charging current adjustment: The BP66FW1242 adjust the charging current of the linear charger by setting the LCS [3:0]. In order to prevent the linear charging function from affecting communication in the Ping Phase, when the Rx is still in the Ping Phase, the linear charger needs to be disabled to prevent a Ping Phase communication failure. When entering the Power Transfer Phase, switch the mode to increase the charging current. Because the Tx has a higher transmission power at this time, a larger charging current will not affect the communication.

The linear charger function provided by the BP66FW1242 includes a current adjustment function. Users can design the current of the constant current charging mode according to their product requirements by using different external resistors. The relationship between the current and resistor value is shown below.

Qi Communication Used with Linear Charger

The linear charging circuit is a low-cost and high-stability method of charging lithium batteries. Because of its operating characteristics, when the battery is in a low-voltage state, there will be a large differential voltage in the circuit which will cause a large temperature rise. For example, when the input voltage is 5V, the battery voltage is 3V and the charging current will be 600mA. This gives a power consumption of (5V-3V) ×600mA=1200mW which will lead to a device temperature rise. The BP66FW1242 can control the Rx received voltage and charging current in real time after entering the Power Transfer Phase. Therefore, the input voltage and charging current can be controlled according to different battery voltages for device temperature control.

Battery Voltage	Input Voltage	Charging Current	IC Power Consumption
3.0V	3.5V	300mA	150mW
3.6V	3.7V	400mA	160mW
3.8V	4.2V	400mA	160mW
3.9V	4.5V	500mA	300mW

Conclusion

In this document, we have learned about the operating principles of the Qi wireless charging, the lithium battery charging modes provided by the BP66FW1242 linear charger and also how to use them together. If you have any problems with the Qi wireless charging design, please contact your local agent for assistance.

Reference Material

Consult the BP66FW1242 datasheet.

For more information consult the Holtek website: http://www.holtek.com.

Versions and Modification Information

Date	Author	Issue	Modification Information
2021.03.25	陳振隆	V1.10	Modify the MCU type to BP66FW1242
2021.01.26	陳振隆	V1.00	First version

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