Let Your Smartphone Power Your Smartwatch—Wirelessly

Introduction

Wireless charging is the next big wave in portable electronics. The elimination of charging cables will change the landscape for powering wearable devices (Figure 1). However, the field is still young, with competing technologies and no definitive standard. Like other critical blocks for portable gadgets, the wireless power receiver must utilize minimal space while meeting the expectation of operating on a single charge for a long time. Accordingly, the receiver must be very small, highly efficient, and compliant with multiple standards. This article discusses the challenges of designing an inductive wireless charging power receiver in today's climate. It then introduces an innovative solution that, in addition to addressing these challenges, enables wireless power transfer to a peer device.

Figure 1. Wireless Charging

Wireless Charging System

Figure 2 is a high-level illustration of an inductive wireless charging system. The charge is automatically initiated by simply placing the device on the charging pad. The transmitting coil, L_T, resides in the charging pad and generates an AC signal of a few hundred kilohertz (WPC and PMA). The energy transfer happens via the magnetic coupling between the transmitting coil and the receiving coil, L_R, in the smartwatch. The AC signal is rectified (V_{RECT}) inside the receiver (Rx) and regulated with an LDO. While power flows forward from the transmitter (Tx) to the receiver, a wireless data signal travels backward, reporting the receiver status to the transmitter. In response to the receiver status the transmitter modulates the transmitted voltage amplitude.

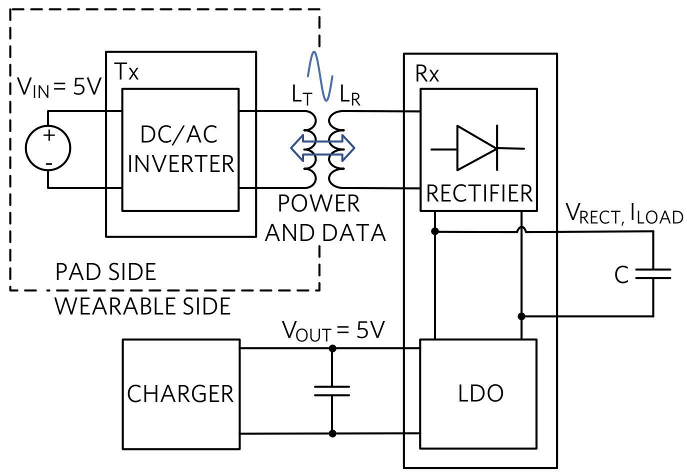

Figure 2. Wireless Charging System

Under heavy load, the rectified voltage (V_{RECT}) is kept very close to the output voltage (V_{OUT}) to minimize the LDO losses. Under light load, V_{RECT} is kept high in anticipation of the negative spike that occurs in the application of a heavy load with a fast-rising edge. The overall system operates as a low-bandwidth closed-loop voltage regulator.

Wireless Power Transmission Standards

Currently, there is no single standard regulating the wireless transmission of power and data from the receiver to the transmitter. Two common standards are PMA and WPC/Qi, both of which are based on inductive charging but with distinctive differences in power and signal transfer. Both standards require the proximity between the charger and receiver to be between one and a few centimeters. Wireless transmission of power over greater distances is also starting to emerge.

Wireless Charging Constraints

Wireless charging eliminates the need to carry a charger or a USB cable while on the go. However, it requires charging pads to be readily accessible. We are now starting to see banks of charging pads available in hotels, restaurants, and airports, making wireless charging increasingly accessible.

A State-of-the-Art Solution

A state-of-the-art wireless charger must address the challenges mentioned earlier—it must conform to multiple standards, have extremely low power consumption, small size, and the ability to work with available charging pads.

The MAX77950 is an advanced wireless power receiver IC that meets the specification requirements for the WPC Low Power v1.2 and PMA SR (v2.0) communication protocols. This device operates using near-field magnetic induction when coupled with either a WPC or PMA transmitter and provides up to 12V of output power.

Active Bridge Rectifier

At the heart of the MAX77950 wireless receiver is a transistor bridge rectifier (Figure 3) that not only takes in the AC input voltage $V_{IN}(f)$ (a sinusoid of amplitude V_{IN} and frequency f), but rectifies and filters it. The four low R_{DSON}, n-channel transistors within the rectifier greatly reduce the power losses compared to a classic diode bridge rectifier implementation. The dashes in Figure 3 outline the MOSFETs' intrinsic diodes.

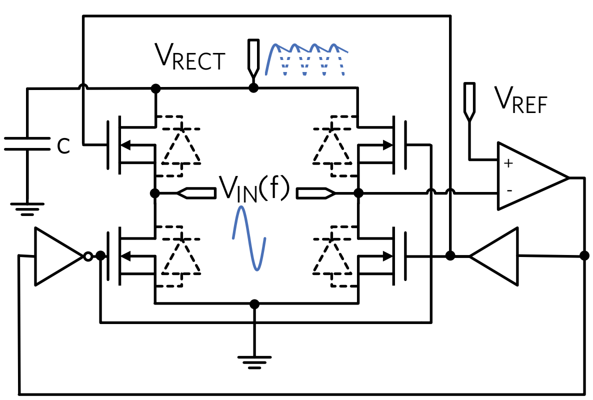

Figure 3. AC-to-DC Active Bridge Rectifier

Finite State Machine

The V_{RECT} output voltage versus load current must meet the specified profile for the application. To this end, the V_{RECT} and corresponding current, I_{LOAD}, are measured (via amplifier A), digitized (through the ADC) and fed to a finite state machine (FSM). The FSM compares the information to a predefined profile table for V_{RECT} vs. I_{LOAD} and calculates the optimum "next" value for V_{RECT}. This information is fed back wirelessly to the transmitter, which adjusts the transmitted amplitude accordingly (Figure 4).

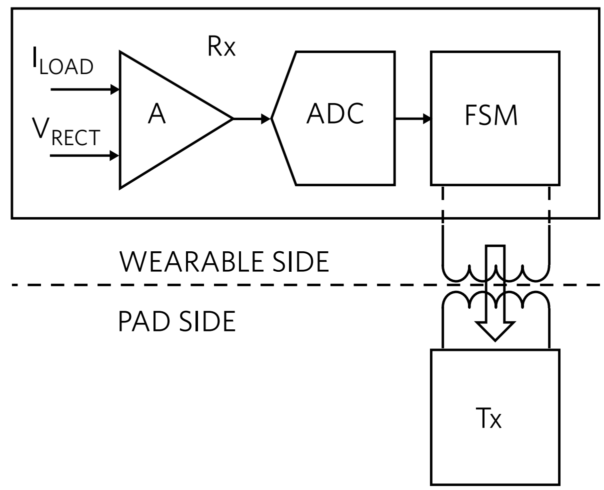

Figure 4. V_{RECT} Feedback Loop

Typical Rectifier Output Profile

The closed-loop system controls the rectified voltage, V_{RECT}, to minimize the power losses across the LDO. For a given application, the voltage profile for V_{RECT} is specified by means of a number (n) of coordinates (V_{RECTn}, I_{LOADn}) in the voltage-current space. These coordinates are loaded into chip registers through the I^2C bus. Figure 5 is a typical example, allowing for four different levels of the V_{RECT} voltages as a function of the load.

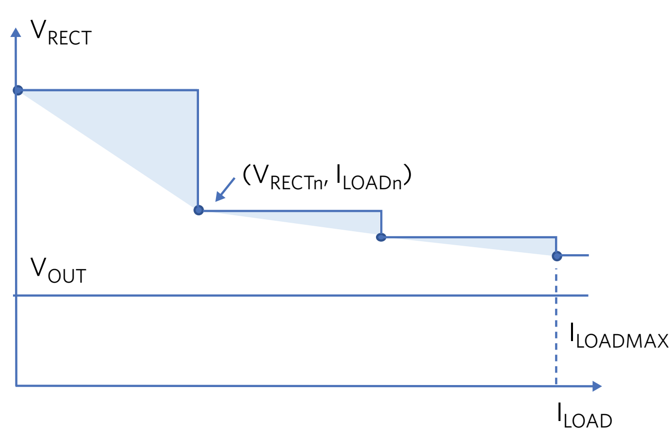

Figure 5. Typical Rectified Voltage Profile

With such coarse granularity, the triangular area under each step, as indicated by the shaded regions, corresponds to wasted power.

MAX77950 Rectifier Output Profile

MAX77950 allows for eight coordinates (corresponding to the blue dots in Figure 6). This provides finer granularity for creating a smoother V_{RECT} profile. Additionally, the FSM measures the load current and forces a V_{RECT} voltage (white dot in Figure 6) that is interpolated between the two specified coordinates (dots 'n-1' and 'n') adjacent to the measured current value.

As a result, the wasted power due to the quantization error is greatly reduced.

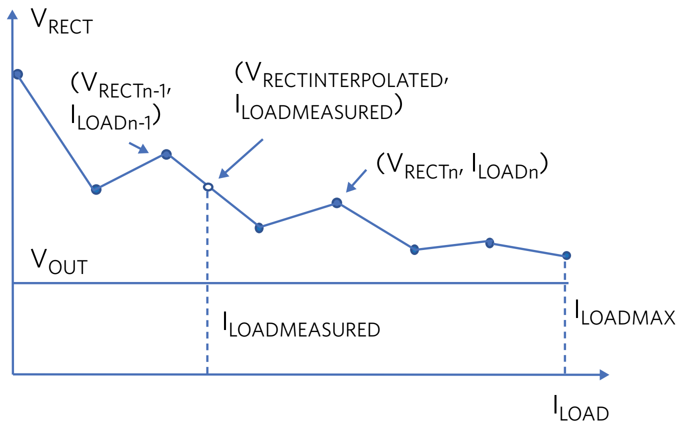

Figure 6. MAX77950 Rectified Voltage Profile

MAX77950 Efficiency Advantage

The combination of a low-loss, active bridge rectifier and a finely adjusted LDO input voltage (V_{RECT}) results in superior efficiency performance. Figure 7 shows the measured system efficiency from V_{IN} to V_{OUT} (Figure 2) for MAX77950 versus a competitive solution.

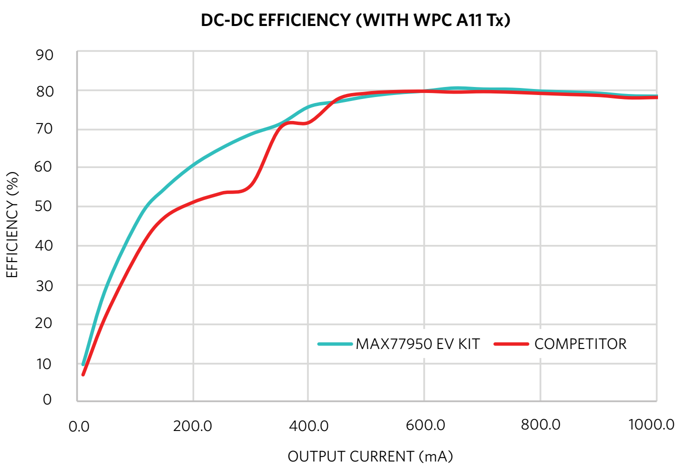

Figure 7. MAX77950 Efficiency Advantage

As expected, the reduced losses translate into a superior efficiency at mid and light loads, with a peak advantage of up to 15% at 300mA.

Peer-to-Peer Charging

As an added advantage, MAX77950 implements PeerPower™ to enable peer-to-peer wireless charging. The IC reconfigures the rectifier block of Figure 3 into a DC-to-AC inverter. The receiving coil now acts as a transmitter that transfers the alternating power to the peer device. Figure 8 illustrates the conversion from DC (V_{IN}(DC)) to square wave (V_{OUT} = $\pm V_{IN}$). Subsequent filtering produces the sinusoidal waveform transmitted to the peer device.

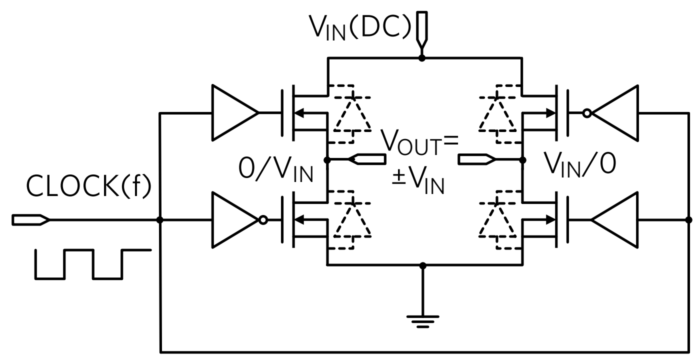

Figure 8. DC-to-AC Active Bridge Inverter

As an example of a typical application, PeerPower allows a wireless transfer of power from a smartphone to a smartwatch. The power drawn from the smartphone is relatively modest but sufficient to recharge the smartwatch. PeerPower is a significant step toward making wireless charging available anytime and anywhere, eliminating the need for the charging pad.

Small Size

The MAX77950 is housed in a small (3.84mm × 2.64mm) WLP, 52 bumps package. The extremely compact packaging, combined with the need for very few external components, make the MAX77950 ideal for even the smallest wearable designs.

Conclusion

We have reviewed a wireless charging system and outlined the challenges of multiple standards, small size, power efficiency, and the availability of charging stations. The tiny MAX77950 provides a unique and compact solution. By operating with both WPC and PMA communication protocols, it overcomes the challenge of multiple standards. The superior efficiency of the device allows for longer untethered operation. Peer-to-peer charging moves the industry closer to devices that can be charged anywhere, anytime.

PMA: Power Matters Alliance

Qi: Open interface standard developed by WPC

WPC: Wireless Power Consortium

Learn more:

MAX77950 WPC/PMA Dual Mode Wireless Power Receiver

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