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Receiver Chip Implements Efficient, Flexible Wireless Charging For Wearables

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Wireless charging is the next big wave in portable electronics. The elimination of charging cables will change the landscape for powering wearable devices (Fig. 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 to operate 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 charging wireless power receiver in today's climate. First, it reviews the basic structure of wireless charging systems as defined under two popular wireless charging standards. Then the article introduces an innovative wireless charging solution based on the MAX77950 wireless power receiver IC. This device incorporates features that improve efficiency while accommodating both WPC and PMA protocols. The IC also enables wireless power transfer to a peer device. The operation of these various features is explained here.

Fig. 1. A smartwatch is one of many wearable devices that will benefit from wireless charging.

Wireless Charging System

Fig. 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 (under either the WPC or PMA standards—more on these below). 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 (because of its small size and low noise). 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.

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 with the application of a heavy load with a fast-rising edge. The overall system operates as a low-bandwidth closed-loop voltage regulator.

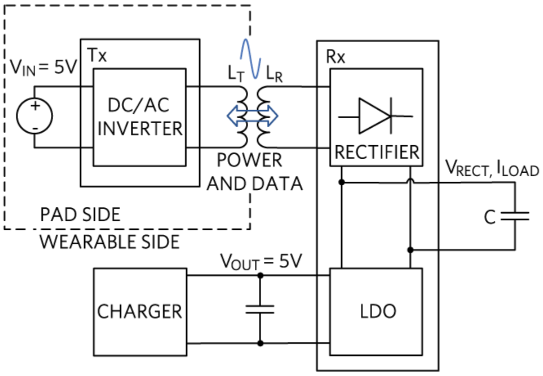

Fig. 2. High-level definition of a wireless charging system. Power flows from the transmitter in the pad through the coils to the receiver in the wearable device. Meanwhile data flows in the other direction so that the receiver's status is reported to the transmitter and power transmission may be adjusted accordingly.

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 the Power Matter Alliance (PMA) standard and the Qi Open interface standard developed by the Wireless Power Consortium (WPC). Both of these standards are based on inductive charging but with distinctive differences both in power and signal transfer. Both standards require a 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 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 this feature increasing 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 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 12 V of output power.

At the heart of the wireless receiver is a transistor bridge rectifier (Fig. 3) that not only takes in the ac input voltage $V_{IN}(f)$ (a sinusoid of amplitude V_{IN} and frequency f), but rectifies it 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 outline the MOSFETs intrinsic diodes.

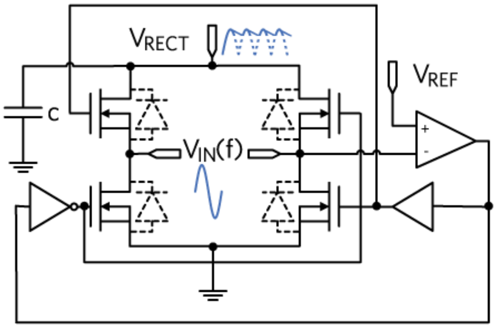

Fig. 3. The ac-dc active bridge rectifier in a wireless receiver both rectifies and filters the ac power signal picked up by the receiver. Use of an active bridge rectifier with low-on-resistance MOSFETs reduces losses versus a standard diode bridge.

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 (via 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 (Fig. 4).

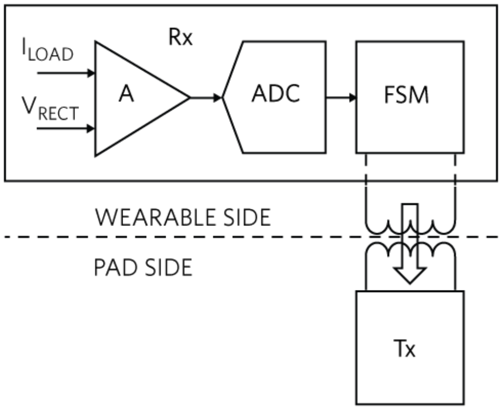

Fig. 4. A V_{RECT} feedback loop in which V_{RECT} and I_{LOAD} are sensed, digitized and compared with desired values in a finite state machine is necessary to ensure that V_{RECT} versus I_{LOAD} matches the profile desired in the application. If not, feedback to the transmitter results in an adjustment of the transmitted voltage.

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 via the I^2C bus. Fig. 5 is a typical example, allowing for four different levels of the V_{RECT} voltages as a function of the load.

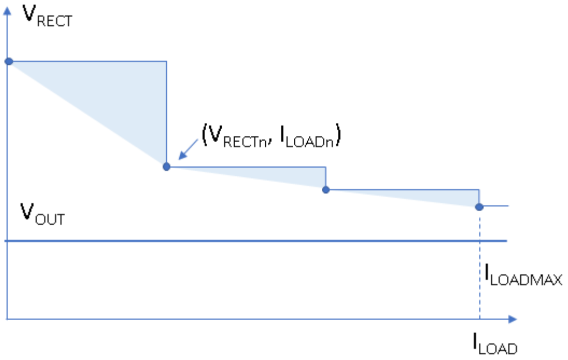

Fig. 5. Typical rectified voltage profile implemented by existing wireless power receiver ICs.

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

In contrast, the MAX77950 allows for eight coordinates (corresponding to the blue dots in Fig. 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 Fig. 6) that is interpolated between the two specified coordinates (dots ‘n-1’ and ‘n’) adjacent to the measured current value.

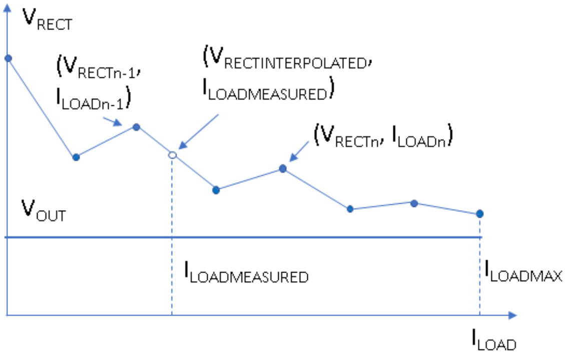

Fig. 6. The MAX77950’s rectified voltage profile. This wireless power receiver IC samples the rectified voltage with greater resolution than the typical receiver, leading to better fine tuning of the received voltage and less wasted power since the LDO voltage drop is better minimized.

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

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

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

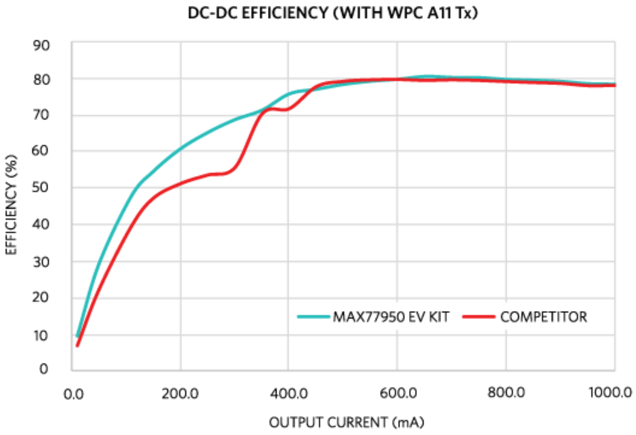

Fig. 7. The MAX77950 achieves better overall efficiency than a competing wireless power receiver because it minimizes losses in its bridge rectifier while also tuning the received voltage for minimum losses in the LDO.

Peer-To-Peer Charging

As an added advantage, the MAX77950 implements a feature called PeerPower, which enables peer-to-peer wireless charging. The IC reconfigures the rectifier block of Fig. 3 into a dc-ac inverter. The receiving coil now acts as a transmitter to transfer the ac power to the peer device. Fig. 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.

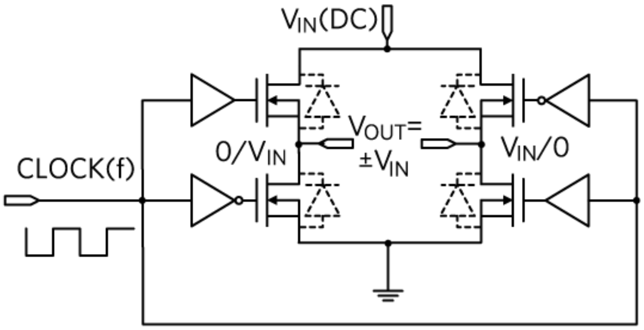

Fig. 8. Dc-ac active bridge inverter.

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.

The MAX77950 is housed in a small (3.84-mm x 2.64-mm), 52-bump WLP package. The compact packaging combined with the need for very few external components makes the MAX77950 well suited for use in 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 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. Its superior efficiency allows for longer untethered operation. Peer-to-peer charging moves the industry closer to devices that can be charged anywhere, anytime.

About The Authors

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For further reading on the design of wireless charging, see the How2Power Design Guide, select the Advanced Search option, see the Popular Topics category and select Wireless Power.