WHITE PAPER

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Developing a multi-channel wireless inductive charger

Introduction

Wireless inductive charging is gaining popularity for use in consumer rechargeable applications such as cordless power tools, net books, notebooks and other power-hungry rechargeable devices. With inductive charging systems, we have the potential of charging multiple devices from a single wall outlet, as well as the convenience and safety of having a vehicle charger that is non-contact (you drive right over it) and sealed from the elements.

The basis of inductive wireless charging is a technology that has been employed for many years in applications. Through the increase in technology of both analog and digital semiconductor devices, coupled with the ever increasing number of rechargeable gadgets, it is beginning to see a surge in use cases, ranging from the single coil (single pad) sub 5 Watt class of devices, to multi-kiloWatt applications. In this article, we will outline the basics of the technology, and how we can accomplish a multiple pad charging device using a single, low-cost Texas Instruments (TI) C2000™ Piccolo™ microcontroller. The advantage of a microcontroller-based solution can be realized through the flexibility of the both the power stage design and communications protocols that are enabled, as well as the number of charging pads that can be controlled through a single device.

In an inductive charging system, there is the inductive charger itself and the device receiving the transmitted power. Similar to the architecture found in many isolated power supply designs, there is a transformer coupling the primary (charging) side and the secondary (receiving) side of the circuit. However, in an inductive charging system, this transformer is made up of two independent coils, separated by an air gap, as well as any elemental sealing, such as a plastic casing. The basic theory of operation is that as power is induced through the primary charging coil, a magnetic field is produced which is then received by the secondary coil and converted back into a voltage. Shielding can be added to either coil of the transformer system to direct the field effects, which can be useful in multiple pad charging applications to eliminate power cross-talk. Intelligent features can also be added to these systems, such as communication to determine varying charge levels and intelligent sensing of foreign objects on the charging pad to disable the charger output.

The Piccolo microcontroller advantage

Leveraging TI's high-performance TMS320C28x™ core, **C2000 Piccolo microcontrollers** provide all of the necessary performance and peripherals needed to control an inductive charging system with a single, stand-alone controller. By offering a code-compatible, scalable, feature-rich platform, designers can migrate throughout the C2000 platform of microcontrollers to implement different inductive charging applications based on price, performance and peripheral requirements while maintaining a common software code base and development environment.

Important high-resolution microcontroller features include:

- Prices starting under $1.50
- Code-compatible scaling from 40MIPS to 90MIPS
- Fixed- and floating-point math capabilities
- Secondary Control Law Accelerator (CLA) core for advanced control loop flexibility
- Integrated FLASH and SRAM Memory
- Single 3.3V power supply
- Up to 19 pulse-width modulation (PWM) channels, including up to 8 PWM channels with 150pS resolution
- Up to 3 on-chip analog comparators
- 12-bit analog-to-digital converter (ADC) with 16 channels and a maximum sampling frequency of 4.6 mega-samples per second
- CAN, LIN, I2C, SPI, UART and USB connectivity options
- Operating temperatures up to 125°C with AEC-Q100 qualified automotive certification

Performance, integration and flexibility

The Piccolo series of devices gives unmatched flexibility for inductive charging applications through the scalability of processing performance, as well as through the integrated, high-performance analog peripherals of the processor. A 32-bit processor architecture means higher precision in control applications, coupled with 12 bit multi-channel ADCs, and high resolution PWM allow hardware designers the opportunity to develop not only multi-channel inductive chargers with a single device but also the flexibility to develop higher power systems or even implement communications protocols. Figure 1 below shows us the basic architecture of a single inductive charging circuit with a current measurement channel used for the Wireless Power Consortium (WPC) "Qi" communications standard.

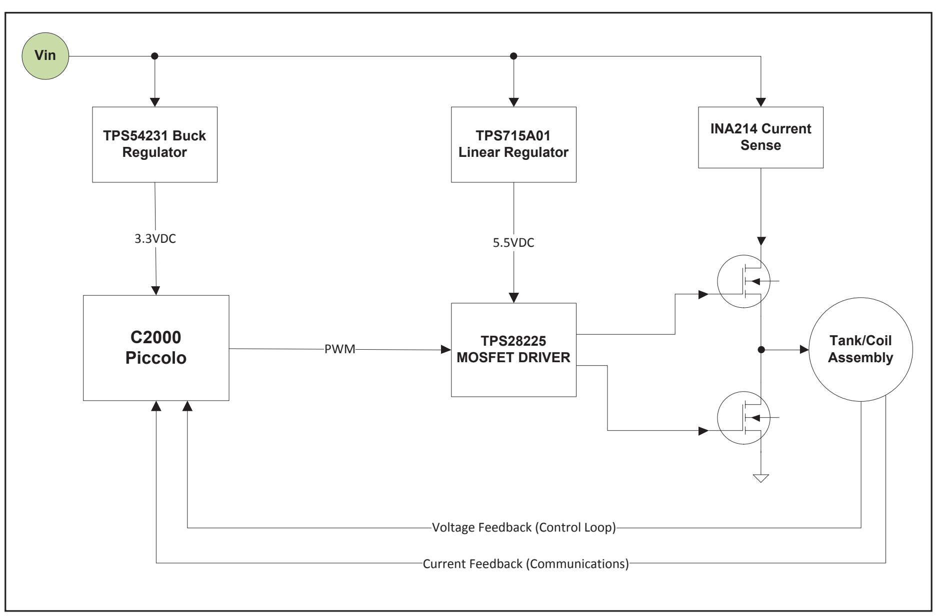

Figure 1: Basic architecture of a single inductive charging circuit with a current measurement channel used for the WPC "Qi" communications standard.

In this architecture, a single PWM channel of the Piccolo device is used for control of the MOSFET driver in a half-bridge configuration, to power the coil assembly. By utilizing Piccolo microcontroller's high-resolution PWM capabilities, higher switching frequencies can be enabled, while at the same time still able to handle very accurate duty cycle modulation to enable the charger side communications.

High-resolution PWM plays a critical role in the design and implementation of DC/DC-based converter systems. By utilizing higher PWM speeds, higher switching frequencies can be achieved and smaller component sizes can be used in the power stage, resulting in higher efficiency and reduced board space. With high-resolution PWMs, there is also the advantage of tighter control of the voltage feedback loop as the PWM duty steps are smaller, reducing the amount of output ripple or "hunting" to find the correct voltage output level of the power supply. For applications that do require Qi communications or similar duty-cycle, packet-based communications protocol, the high-resolution PWM channels of Piccolo also offer the advantage of being able to very tightly control the duty cycle (again, to 150ps resolution) to enable these features. Figure 2 below is a graphical representation of resolution based limit cycling due to the difference between conventional and high resolution PWM.

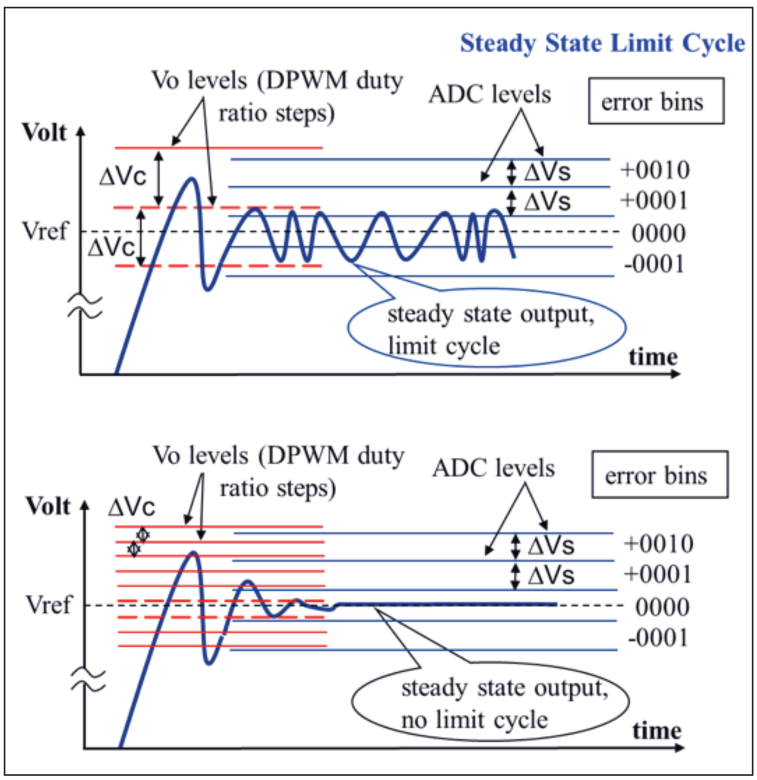

Figure 2: Graphical representation of resolution based limit cycling due to the difference between conventional and high-resolution PWM.

Referring back to the system implementation diagram, notice that there are two feedback loops from the coil assembly – one feedback loop for voltage and one feedback loop for current. The voltage feedback loop is used to control the power stage itself, in this case, a resonant half-bridge, while the current loop is used to demodulate the communications protocol standard associated with the WPC "Qi" standard. In a WPC Qi-compliant system, the load current of the primary side coil is sensed and demodulated to determine the signaling data. The receiver side of the charging system, when placed on the charging surface, applies a series of load pulses to the secondary side coil pertaining to the communications protocol. If a design does not require WPC Qi compliancy, such as for high-wattage applications or applications where non-standardization is preferred, this current feedback loop can be omitted, saving us an ADC channel.

As one can see, based on this single channel implementation, only one PWM channel is used, as well as two ADC channels. With the amount of processing power available in the Piccolo series of devices, one can very easily scale this up to have a single microcontroller controlling multiple power charging circuits. For more advanced, higher power systems, many designers will employ a four-switch full bridge topology, which is still able to be accomplished on the lower cost devices in the C2000 platform.

Aside from the power stage control itself, one can also utilize the on-chip peripherals of the C2000 device to enhance system protection. With up to three analog comparators integrated on chip, a designer can also implement a hardware-controlled over-voltage or over-current protection circuit for the primary power stage without tying up any processor overhead. For this, there are two methods of implementation – a true comparator function through a GPIO channel controlling an external switch in the circuit or via a shut-down of the PWM channel controlling the power stage itself internally. In both instances, triggering speeds of less than 50ns are achievable.

Getting Started

TI offers a comprehensive set of evaluation and development tools for the C2000 platform of microcontrollers, starting at just $17 with the introduction of the **C2000 LaunchPad**. This low-cost evaluation kit includes a Piccolo F28027 microcontroller with breakout pins allowing access to all of the device peripherals. This board also includes a built in, isolated USB-JTAG interface, offering protection for the user's PC when working on digitally controlled power stages. TI, through the **C2000 controlsuite™** software, also offers a set of comprehensive software libraries for digital power designs including control-loop processing blocks such as that for a resonant LLC power stage, as well as for hardware setup, such as initializing the high resolution PWM and ADC channels. For more information on these software resources, as well as the complete lineup of C2000 hardware, application notes and programming resources, please visit **www.ti.com/controlsuite**. For more information on the C2000 LaunchPad, please visit **www.ti.com/c2000launchpad**.

For More Information

For more information on the Wireless Power Consortium and the "Qi" communications protocol, please visit **www.wirelesspowerconsortium.com**.

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