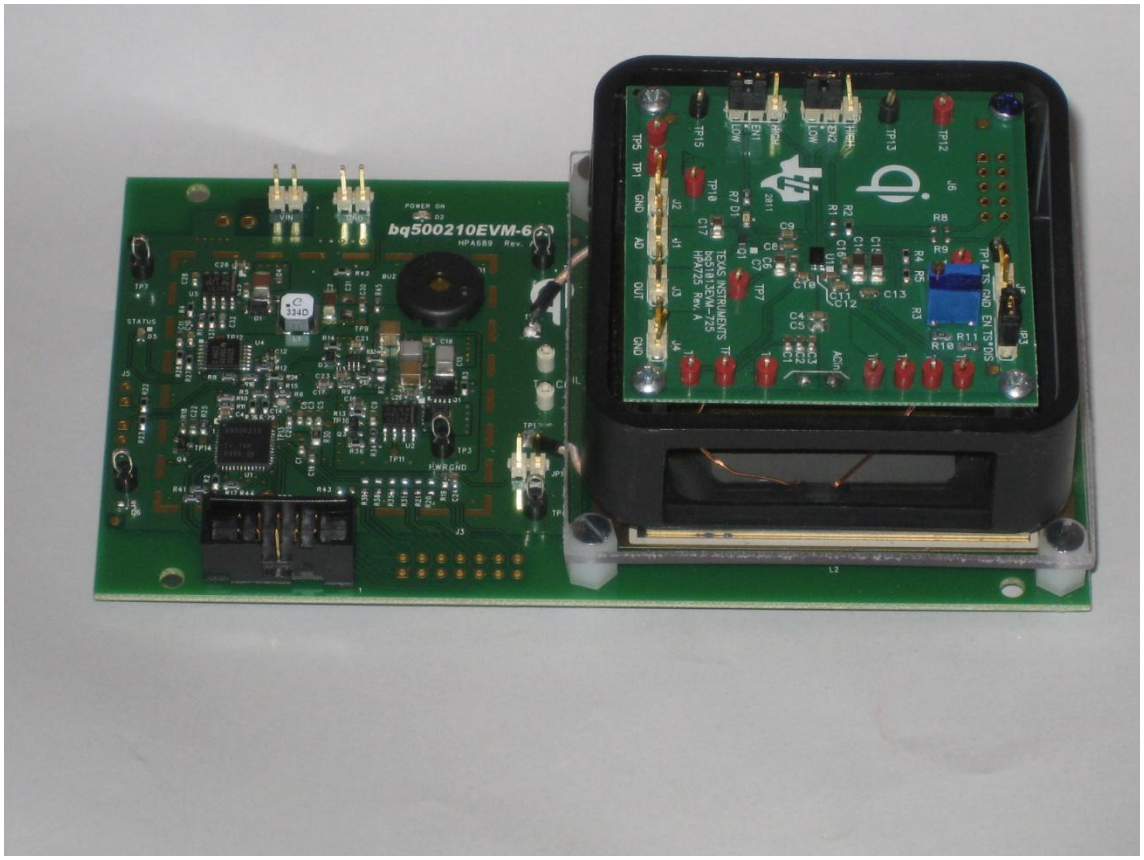
Measuring Qi power with the MDO

By Steve Sandler, Picotest



One of the up and coming technologies is "Qi" (pronounced Chee) wireless battery charging. The Wireless Power Consortium (WPC – www.wirelesspowerconsortium.com) was established in Dec. 2008 with a mission to promote a standard for wirelessly recharging portable electronics. Currently more than 100 companies are members of the consortium. More than 75 Qi enabled products were demonstrated at the 2012 International Consumer Electronics Show in Las Vegas. The market is expected to grow to 500 million units per year by the middle of this decade.

From a measurement perspective, the Qi chargers offer some interesting challenges. Though the wireless charger is designed to produce 5W of charging power, the Energy Star goals require high operating efficiency and low standby power. This is more complicated in a wireless charging system than in a typical charger, since the wireless system requires both a transmitter and a receiver. Other complications exist due to the shielding requirements, necessary to protect sensitive electronics and the battery from the RF fields and foreign object detection in order to prevent heating of nearby metal objects.

While both interesting and challenging, the Qi system includes low frequency modulated RF, digital and analog circuits all on a single board.

The charging system uses digital communication, both for JTAG debugging, and also for the purpose of transferring data between the secondary and primary circuits across the resonant link. The charger's output voltage is monitored by a secondary side microcontroller that generates signals and uses modulation techniques to transfer information to the primary side. The information is demodulated on the primary side where it is interpreted by the primary side microcontroller. The modulated information is organized into information packets that have preamble bytes, header bytes, message bytes and checksum bytes. Per the WPC specification, information packets can be related to Identification, Configuration, Control Error, Rectified Power, Charge Status, and End of Power Transfer information.

This application note is not intended to provide design assistance or education regarding the Tektronix MDO4000 oscilloscope, but to show the unique capability of the MDO4000, along with a few probes and accessories, to measure all three domains; time, digital and spectrum.

The equipment used for our testing includes the Tektronix MDO4104-6 multi domain oscilloscope, which includes a 4 channel oscilloscope, a 16 channel logic analyzer and a 50kHz to 6GHz spectrum analyzer.

The device we are testing is a Texas Instrument Wireless Power set, including a Bq500210EVM-689 transmitter and Bq51013EVM-725 receiver. The DC input power is provided by a Tektronix PWS4323 programmable power supply.

We will look at the radiated and conducted EMI from the charger, which is detailed in a separate application note[i]. Details for the equipment used for the EMI measurements can be found in that article.

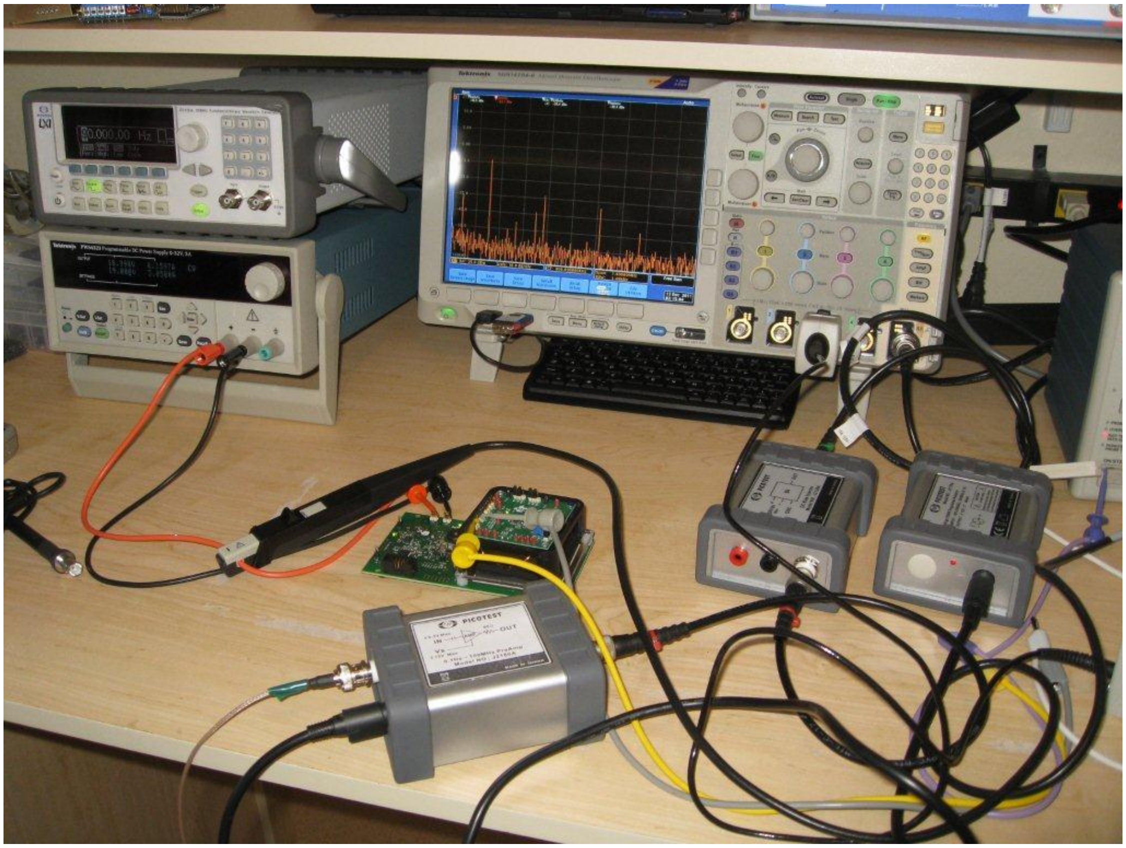


Figure 1 The test bench for measuring the Qi Charger. The Picotest Signal Injectors are used along with the MDO to make the measurements.

The Qi charger power stage is based on a Half Bridge LLC topology resonant converter, controlled directly from the primary side charger controller. The resonance converter is frequency modulated over a frequency range of approximately 110kHz to 205kHz in order to regulate the charger output power.

There are several ways to look at the LLC resonant waveforms. Figure 2 shows the resonant link current, measured with a voltage probe connected to the resonant capacitor link and also shows the resonant frequency. This current could also be seen using a current probe, such as the TCP312 with the TCPA amplifier or the TCP0030 or via the I_Sense testpoint on the transmitter board. The RF channel is connected to a scope voltage probe via the Picotest J2180A preamplifier. The preamplifier provides a high input impedance and a 50 Ohm output impedance, facilitating a voltage probe connection to the LLC half bridge switch node. Without this injector, and the impedance conversion it provides, the measurement cannot be easily made. The RF channel displays the fundamental operating frequency of 141kHz and is also rich with the odd harmonics associated with the 50% duty cycle switch voltage. The lack of even harmonics provides assurance that the duty cycle is precisely 50%.

Figure 3 shows the LLC half bridge converter switch node on the upper analog trace confirming the 50% duty cycle waveform visually.

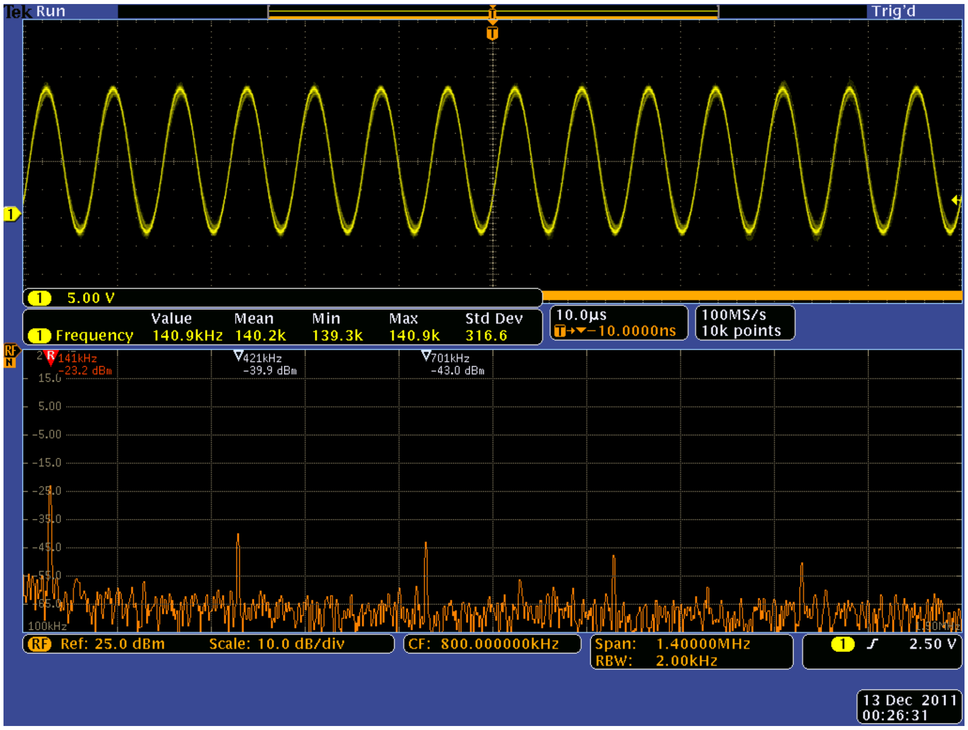


Figure 2 LLC half bridge resonant link current top trace, LLC half bridge switching spectrum lower trace.

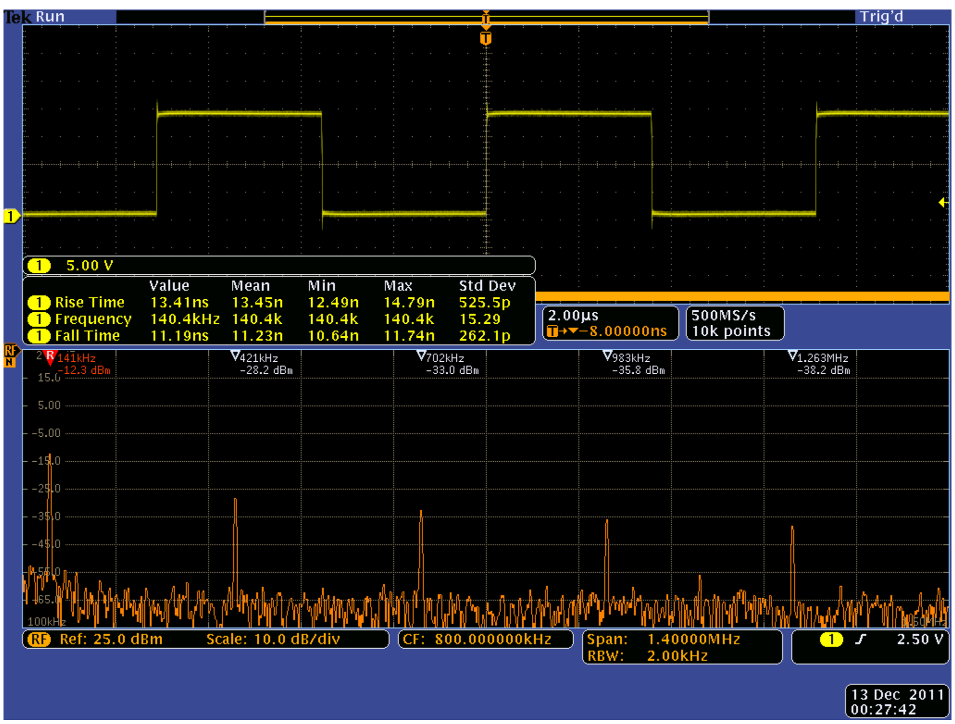


Figure 3 LLC half bridge switching voltage upper trace, LLC half bridge switching spectrum lower trace.

The MDO is also capable of measuring higher frequency signals, such as EMI. Figure 4 shows the radiated EMI over a frequency range of 100kHz to 2MHz from the LLC half bridge switching, as well as from a low power 600kHz buck regulator used to efficiently convert the 19VDC input voltage to 3.3V required by the transmitter controller. Figure 5 shows the radiated EMI signals from the LLC half bridge switches, 600kHz buck regulator and 31MHz microcontroller over a frequency range of 5MHz to 50MHz. The MDO4000 can support such measurements over a range of 50kHz to 6GHz.

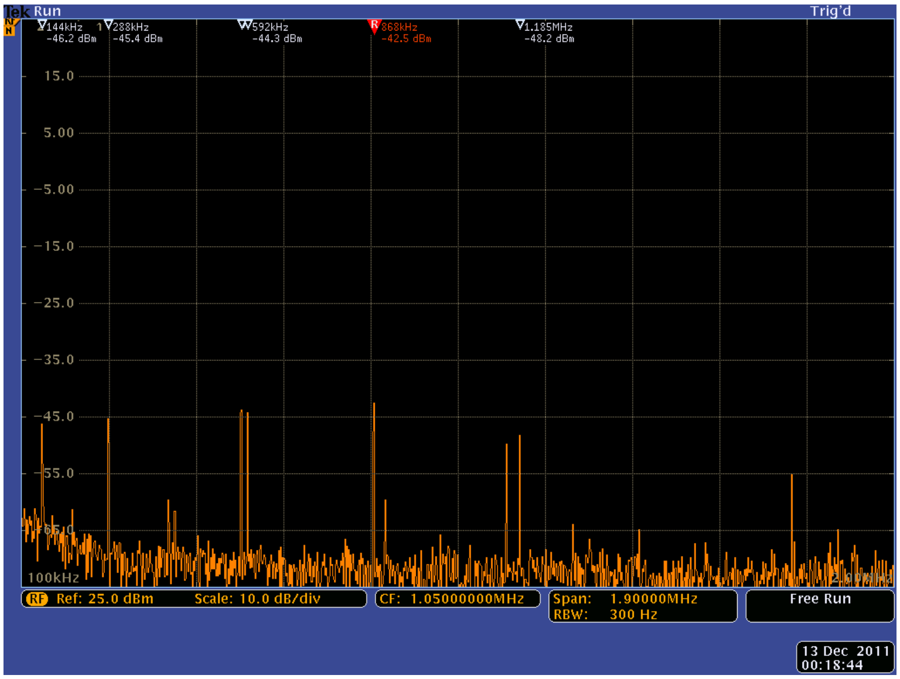


Figure 4 radiated EMI signals from the LLC half bridge switches and the 600kHz buck regulator.

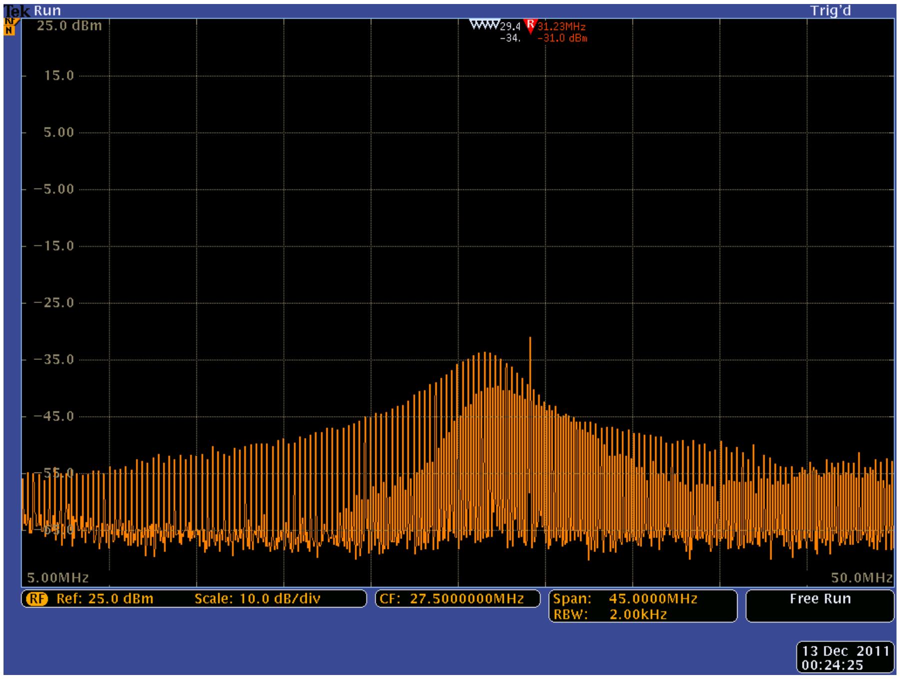


Figure 5 radiated EMI signals from the LLC half bridge switches, 600kHz buck regulator and 31MHz microcontroller.

The digital communications across the resonant link are accomplished using either resistive or capacitive techniques. Either method results in an amplitude modulation of the primary voltage. The spectrum-time capabilities of the MDO4000 are used to show the amplitude vs. time waveform in the upper trace of Figure 6 while the lower trace shows the resonant link signal. This digital information can be extracted using either a voltage probe or a near field H probe, connected to the MDO4000 RF input via the Picotest J2180A preamplifier. We used a near field probe fit, available from Electro Metrics.

Digital communications are also available using an I2C bus and a JTAG connector. Since little information is provided by Texas Instrument regarding these signals, and since we don't have an I2C EMBD module configured for this test we did not monitor them in this application note, however, the MDO is capable of decoding the I2C bus using the optional DPOEMBD application module.

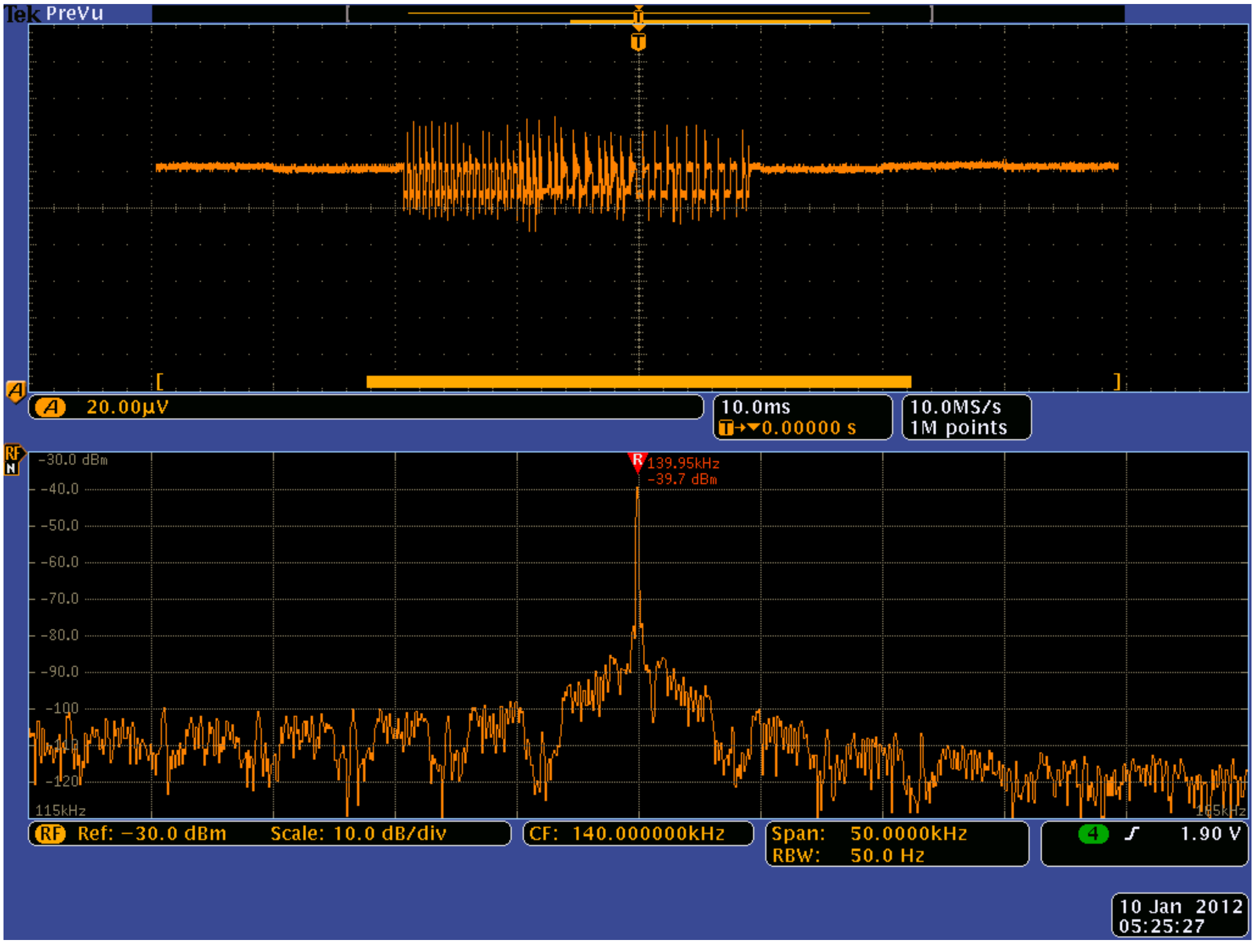


Figure 6 RF input showing the spectrum of the LLC half bridge converter in the lower trace and the amplitude modulation, using the spectrum time amplitude vs time function to show the communication signals in the upper trace.

The communication signals can be seen in the time domain. Figure 7 shows the communication modulation control signal, generated by the receiver controller while Figure 8 shows the amplitude modulation of the transmitter primary winding voltage. Both of these signals are measured using a TDP0500 differential voltage probe for maximum clarity and minimum circuit loading. The differential probe is more important in the measurement of the primary voltage than it is for the receiver controller voltage. This is due to the receiver control signal being ground referenced and relatively low impedance, while the primary voltage is floating and being part of the resonant tank circuit the primary voltage is more sensitive to capacitive loading due to probing.

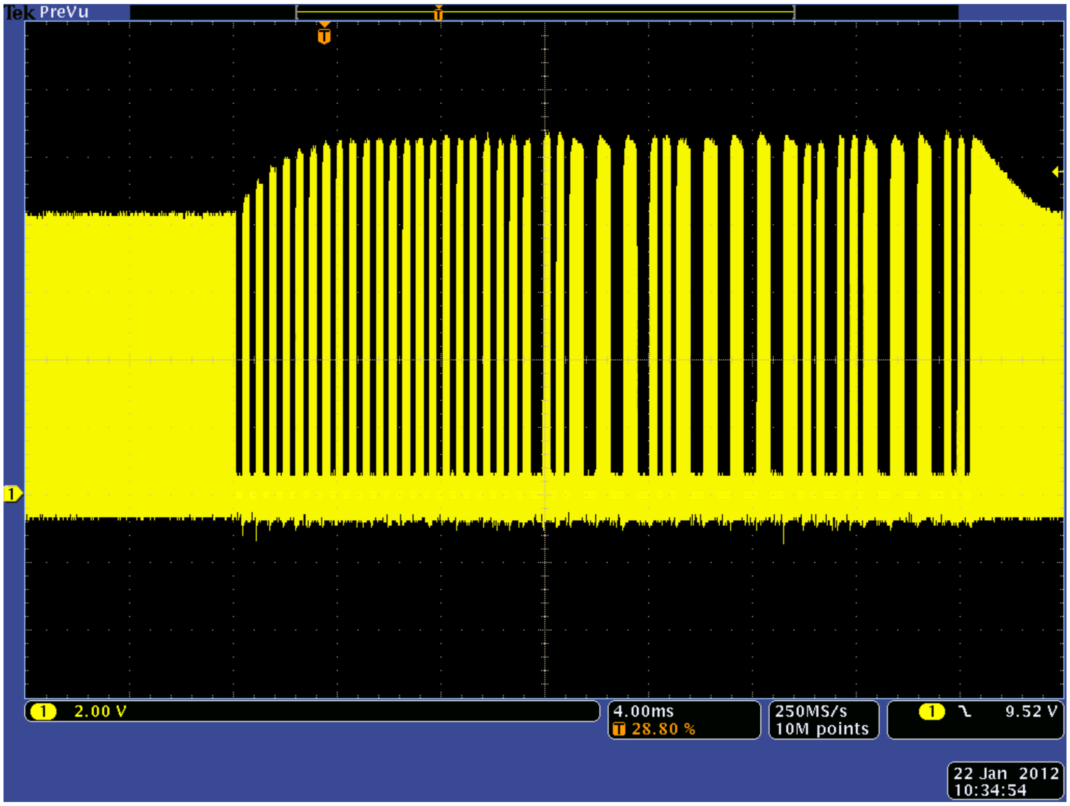


Figure 7 Receiver modulation control pin measured with the TDP0500 Diff probe.

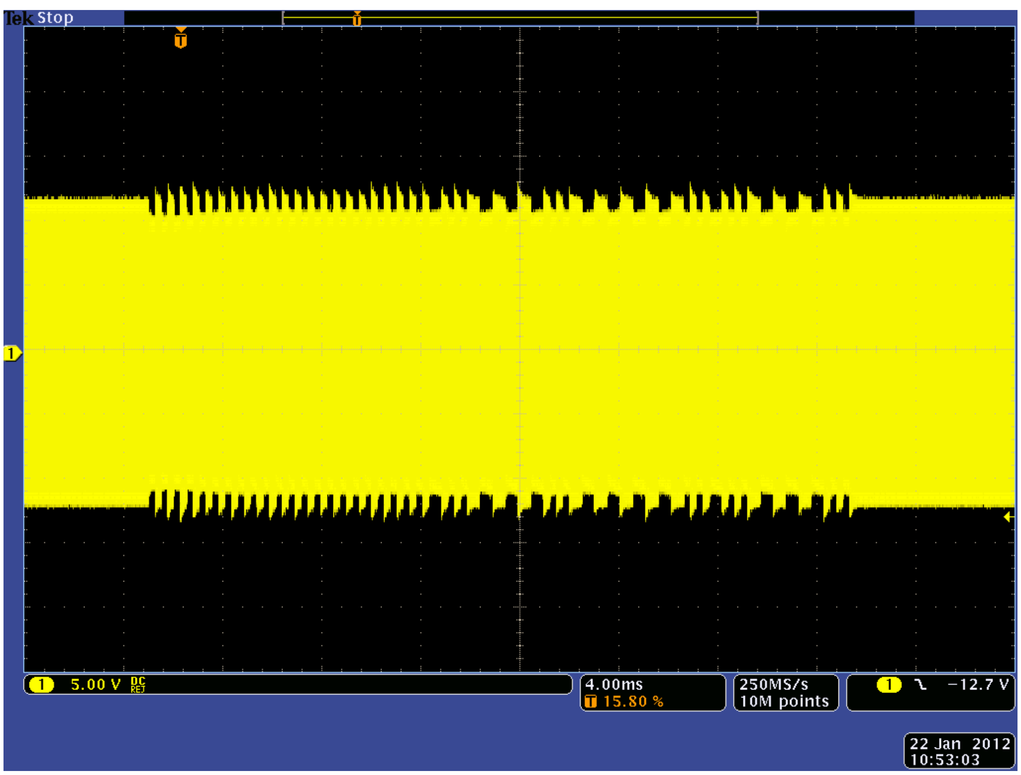


Figure 8 Primary coil voltage measured with the TDP0500 Diff probe.

The Qi charger ultimately provides a 5V, 1A output to charge portable electronic batteries. The LLC half bridge converter coarsely regulates the secondary side voltage, The output is then precisely regulated using a 5V low dropout regulator (LDO).

Figure 9 shows the result of a small signal step load applied to the 5V output, using a Picotest J2111A Current Injector, in order to measure the dynamic response and control loop stability of this final output regulator. The current injector is used in place of an electronic load to allow faster rise and fall time, but also due to the capacitive loading an electronic load often presents, which can can distort the results.

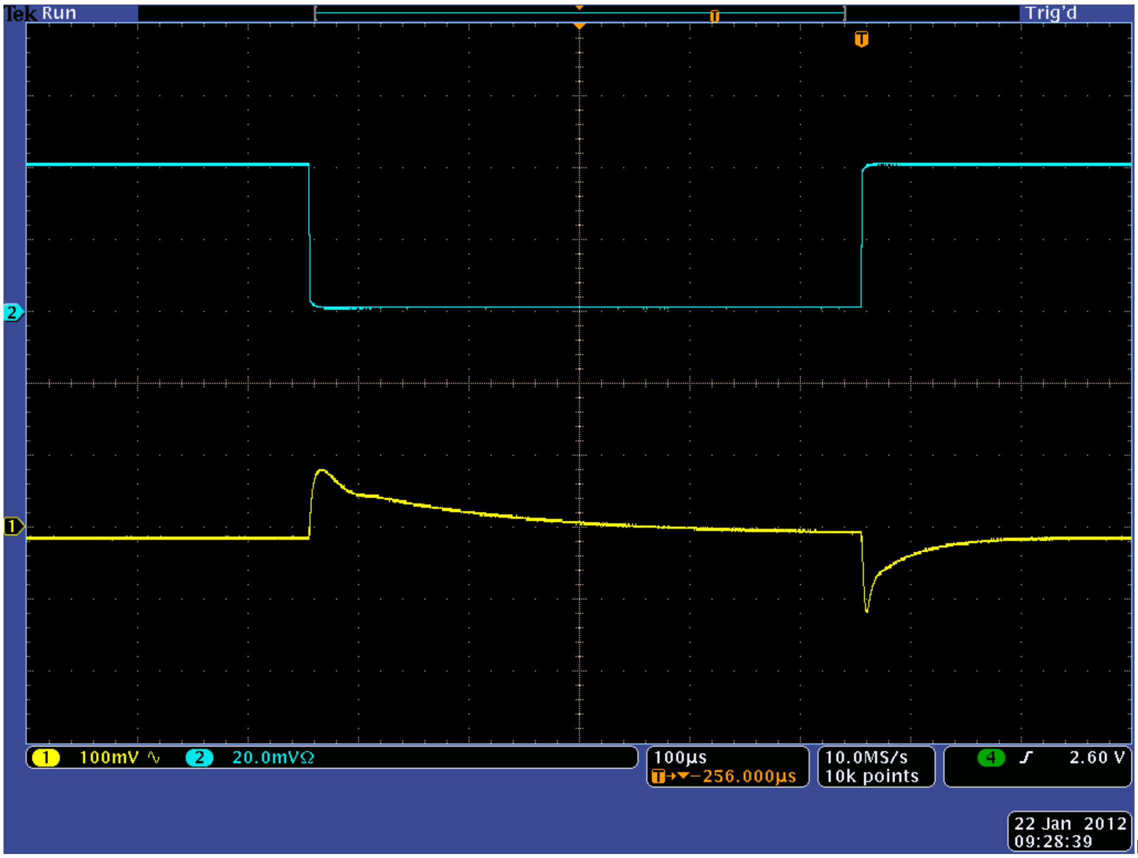


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Figure 9 Dynamic load response of 5V output. Blue trace is current (20mA/Div) and yellow trace is voltage (100mV/Div).

These test results demonstrate the unique ability of the MDO4000 to measure the logic, RF and analog functions of the Qi wireless battery charger, aided by only a few probes and accessories. In the case of the communication signal, the MDO measured the signals in more than one domain. This included spectrum-time, as well as the time domain. This allowed us to see the signal at its point of origin, within the RF link signal, and at the point of receipt across the transmitter winding. We also measured the analog step load performance of the final LDO output regulator and were able to capture the EMI signals. Using the DPO4EMBD application module, it is also be possible to decode the I2C bus. The MDO4000 is obviously well suited to testing wireless technology. Having all of this capability in a single machine both saves money and valuable bench space compared to separate logic and spectrum analyzers and an oscilloscope.

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[i] 1) Measuring EMI with the MDO, Steve Sandler, Picotest, December, 2011, White Paper