WIRELESS CHARGING SOLUTIONS - EPP TRANSMITTER AND RECEIVER

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# NXP Wireless Power Solutions Portfolio

**NXP type in Qi A28, MP-A4, MP-A8, MP-A9**

<table>
<thead>
<tr>
<th>Power Level</th>
<th>Transmitter Options</th>
<th>Receiver Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>200W</td>
<td>WCT-200WTX 30W - 200W</td>
<td>WPR-200WRX 30W – 200W</td>
</tr>
<tr>
<td>15W</td>
<td>WCT-15WTXAUTO 15W Qi, MP-A9 5W PMA</td>
<td>WPR1500-BUCK 5-15W Qi</td>
</tr>
<tr>
<td></td>
<td>WCT-15WTXAUTOS 15W Qi, MP-A9 Autosar</td>
<td>WPR1500-LDO 5-15W Qi</td>
</tr>
<tr>
<td></td>
<td>WCT-15WTXMULTI 15W Qi, MP-A8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WCT-15W1TXFF 15W Qi, MP-Ax, Fixed Frequency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WCT-15W1COILTX 15W Qi, MP-A4</td>
<td></td>
</tr>
<tr>
<td>5W</td>
<td>WCT-5WTXMULTI 5W Qi A28, 5W PMA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WCT-5WTXAUTO 5W Qi A13, 5W PMA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NXQ1TXH5 5W Qi A11 Integrated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WCT-5W1COILTX 5W Qi A11 Flexible</td>
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</tr>
<tr>
<td>300mW</td>
<td>NFC TX</td>
<td>NFC RX</td>
</tr>
</tbody>
</table>

**Technology Types**

- Single-Coil Tx
- Multi-Coil Tx
- Single-Coil Rx
- Industrial/Auto

**Production**

- Execution
- Planning
- Proposal
EPP TX CONTROLLER AND REFERENCE DESIGN
EPP TX Transmitter for consumer
--WCT1011CFM and WCT1111CLH

WCT1011CFM and WCT1111CLH Main features:

**DSC based on 32-bit 56800EX core**
- Up to 100 MIPS at 100 MHz core frequency in fast mode
- DSP and MCU functionality in a unified, C-efficient architecture

**On-chip memory**
- Up to 64 KB flash memory
- Up to 8 KB data/program

**Analog**
- Two high-speed, 8-channel, 12-bit ADCs with dynamic x1, x2, and x4 programmable amplifier
- Three analog comparators with integrated 6-bit DAC references,
- Two 12-bit digital-to-analog converter (DAC)

---**One eFlexPWM module with up to 12 PWM outputs, including 8 channels with high resolution NanoEdge placement**

Timers, Clocks and operating characteristics is designed for Wireless charger application.

**Package**

WCT1012: 32PIN QFN suitable for the compact dimension application.
WCT1111: 64PIN LQFP for more feature application.
EPP TX Transmitter chip for Automotive
--WCT1013AVLH

Main features:

WCT1013AVLH

**DSC based on 32-bit 56800EX core**
- Up to 100 MIPS at 100 MHz core frequency in fast mode
- DSP and MCU functionality in a unified, C-efficient architecture

**On-chip memory**
- Up to 288 KB flash memory
- Up to 32 KB data/program

**Analog**
- Two high-speed, 8-channel, 12-bit ADCs with dynamic x1, x2, and x4 programmable amplifier
- Three analog comparators with integrated 6-bit DAC references
- 1 12-bit digital-to-analog converter (DAC)

--- **One eFlexPWM module with up to 12 PWM outputs, including 8 channels with high resolution NanoEdge placement**

Timers, Clocks and operating characteristics is designed for Wireless charger application.

**Package**

WCT1013AVLH: 64PIN LQFP for more feature application.
MP-A8 15W MULTI-COIL TRANSMITTER
WCT-15WTXMULTI

- **Target Applications:**
  - Fast Mobile Charger, Tablet Charger, Free positioning

- **Features and Enablement:**
  - Compliant with WPC-Qi Extend Power Profile (15W) specifications
  - 1st WPC free positioning multiple coils medium power transmitter solution using frequency control, duty cycle control, phase shift control, and topology switch
  - On-chip digital demodulation
  - Back compliant with WPC low power specifications
  - Support MP FOD framework – Q factor and power loss FOD methods.
  - Low standby power using Our proximity sense technology
  - Voltage/current/temperature protection
  - Robust foreign object detection algorithm
  - 12V input

- **Availability & Certification:**
  - Qi Certificated
**Sample Circuits**

- Coil Current
- Input Current
- Input Voltage
- Temperature

**Power Supply Management Circuit**

- +12V Analog
- Vbus
- 3.3V Digital
- 3.3V Analog

**MP TX Multi-coil**

- by NXP

**WCT1111**

- Coil Current sensing
- PWM & Driver EN

**Q Factor Detection**

- Inverter & LC Resonant Circuit

**Q Factor Low Voltage source**

- Vin +12V

**Sigle chip for DDM And Q-factor detection**

**Multi-coil solution with Multi inverters or Coil Switched Mosfets.**
Wireless Charger TX for Consumer WCT1013AVLH

- Based on WPC **MP-A9 (NXP Topology)**
- 15W wireless charging platform multi-coil free position with Fixed frequency
- NFC Feature and low-cost digital buck-boost
- Flexible for additional feature

WCT1013A Module

- Features
  - Compliant with the Qi v1.2.3 specification
  - Integrated digital demodulation in chip
  - Supports FOD based on quality factor (Q factor) change
  - Supports FOD based on calibrated power loss accounting
  - Supports Qi MP receiver with 15W output power capability
  - Supports multiple types of RX modulation signals (AC capacitor, AC resistor, and DC resistor)
  - 100MHz core frequency
Sigle chip for DDM
And Q-factor detection

Low cost Digital buck-boost
Solution

Rail voltage can be 3~24V,
Support all the RX Vbus
requirements
Power circuits for DCDC stage

Input: 8~16Vdc
Output (Vrail): 5~24Vdc/ 30W

Topology selection: Buck-boost, Sepic, Flyback

Buck-boost is selected for the solution to achieve the best efficiency
Control can be analog and digital method

Main Power circuit

Switch status
Control strategy for buck-boost converter

Buck mode:

- the bandwidth is about 3.14 kHz.

Boost mode:

- the bandwidth is about 2.69 kHz

*Easily to debug the control PI parameter to get best performance*
MP-A9 Coil and Resonance parameter

= Dimension of coil unit =

= Coil unit Assembly =

= Electrical Characteristics =
- $L_s: 9.8\mu H \pm 10\% @ 100kHz (Coil1,3)$
- $L_s: 10.2\mu H \pm 10\% @ 100kHz (Coil2)$
- $R_s: 0.06\Omega$ typ. @100kHz (Coil1,2,3)

$C = 400nF\ C0G\ 100V\ 1206$
Efficiency and Charging Area testing MP-A9

**Efficiency@LP RX**

5W RX

**Efficiency@MP RX**

15W RX

Charging Area
WPR1500 buck RX
PCB Layout Considerations and EMC design

--PCB Consideration

1. Placement of the whole board.
2. Power Circuit routing, will effect the efficiency and sensing noise.
3. GND routing strategy. Separate the copper of power GND and control GND (connect at a single point), still separate the GND and AGND, connected with 0 ohm resistor
PCB layout for GND idea

Pgnd
Dgnd
Agnd
The MP TX system can pass the EMI test with the qualified adaptor without additional filter, and below design items should be considerate:

A, Input filter circuits are added.
B, The full bridge Mosfet driver resistor can be adjusted.
C, Mosfet Snubber circuit should be added to decrease the spike on the mosfet when switching. This circuit is show on the example schematic.
D, Shielding for the power boards and the coil( just cover the low frequency radiation)
EPP SYSTEM DEMODULATION METHOD
Communication essential

Receiver to Transmitter

ASK (Amplitude Shift Keying)
Speed: 2 K bit/s
Bit-encoding: bi-phase
Byte encoding:
Start-bit, 8-bit data, parity-bit, stop-bit
Packet structure
  Preamble (>= 11 bit)
  Header (1 Byte): Indicates packet type and message length
  Message (1 .. 27 Byte):
    One complete message per packet
    Payload for control
  Checksum (1 Byte)
NXP digital demodulation circuits

Very low cost hardware circuits (RC divider), and this signal can be used for RX detection, FOD and so on.
Coil current sampling

Synchronized sampling

- The communication signal (2KHz) is modulated onto the power PWM signal (110~205KHz). The ADC sampling is synchronized with PWM signal. The sampling position is located at the peak of the waveform.
Signal detection result

One example of moving window sum channel with zero crossing edge detection

The differential bi-phase encoding:

Actual sampled coil current data:

After moving window filtering, the output is shown as the right-hand figure. Then we can use zero-crossing criteria to determine the edge position and corresponding edge time. The edge time will be used by Qi communication decoder to decide if a bit ‘0’ or ‘1’ is received.
EPP SYSTEM Q FACTOR DETECTION
RX Q value definition

In the Qi V1.2.2, the MP-RX will report itself Q Factor(tested with MP-A1 coil combined together), then if the online Q measured is lower than this Q threshold, FO is near TX and RX coil.
Lcoil and Lcoil Resistance testing---Free Resonance Method

- \( Q_{LC} = \frac{\pi}{(-\ln(Rate))} \), Rate is the value of decay rate of resonance signal
  - one signal is required: \( V_{cap2} \); the peak value of resonance signal is used to calculation;

Through this LC circuits’ \( Q_{LC} \), we can get the Coil inductor and Coil resistance, then TX can RX coil’s(combined together) Q Factor is calculated.
Resonance signal

The resonant waveform after add the pulse to the LC circuits

We can get the useful information from this free wheel LC resonance
Q measurement details

2. with the peak voltage of resonance signals, the decay rate could be calculated. Through the formula \( Q_{lc} = \frac{\pi}{\left(-\ln(\text{Rate})\right)} \), Q factor of the LC circuit could be get.

3. after we get the \( Q_{lc} \left( Q = \frac{\sqrt{L/C}}{R_{lc}} \right) \), then we can get the resonance circuits \( R_{lc} \):

\[
R_{lc} = \frac{\sqrt{L/C}}{Q}
\]

as we have know the \( R_c \), then the coils’ \( R_{lcoil} \)

so : \( Q_{coil} = \frac{X_{lcoil}}{R_{lcoil}} \)
Implement on NXP’s MP solutions

Free Resonance Q factor detection signal
EPP RX DESIGN
WPR1516 IC IP Features

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal LDO supports operation voltage of 3.5-20V</td>
<td>Easy to support different types of Transmitter and different working condition</td>
</tr>
<tr>
<td>Flash-based IC based on ARM Cortex-M0+ core</td>
<td>Provides a popular development ecosystem and allows for customized differentiation</td>
</tr>
<tr>
<td>Defined architecture based on WPC MPWG specification</td>
<td>Any “Qi” compliant transmitter can charge WPR1516 receiver solutions</td>
</tr>
<tr>
<td>Specially designed FSK and CNC models</td>
<td>Eases MPWG bi-directional communication development</td>
</tr>
<tr>
<td>12-bit ADC and PGA</td>
<td>Provides an easy solution for small system-level power loss detection to achieve FOD</td>
</tr>
<tr>
<td>USB/Adaptor Switcher</td>
<td>Sets wired charging as higher priority to help save power</td>
</tr>
<tr>
<td>IIC and UART</td>
<td>Supports the communication between the receiver and main application processor for security or content delivery</td>
</tr>
</tbody>
</table>
## WPR1516 IC IP Features - Continue

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMP feature</td>
<td>Enables safe hardware over current or over voltage protection</td>
</tr>
<tr>
<td>Alternative package options</td>
<td>Easier to manufacturing and helps save PCB space</td>
</tr>
<tr>
<td>FreeMaster UI</td>
<td>Friendly user interface to encourage user interaction</td>
</tr>
<tr>
<td>Pre-validated according to WPC compliance testing procedure</td>
<td>Saves time to market and development costs</td>
</tr>
</tbody>
</table>

### Package Offering:

<table>
<thead>
<tr>
<th>Samples Part Number</th>
<th>Max. Freq.</th>
<th>Pin Count</th>
<th>Package</th>
<th>Size</th>
<th>Ready</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWPR1516CFM</td>
<td>Rx</td>
<td>32</td>
<td>QFN32</td>
<td>5x5x0.65</td>
<td>Now</td>
</tr>
<tr>
<td>PWPR1516CAL</td>
<td>Rx</td>
<td>36</td>
<td>WLCSP</td>
<td>3.1x3x0.6</td>
<td>Now</td>
</tr>
</tbody>
</table>
### Medium Power Receiver Solution

**Key Features:**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance with the medium power WPC Qi specification</td>
<td></td>
</tr>
<tr>
<td>Input power (3.5 V ~ 20 Vac peak) from the transmitter via the receiver coil</td>
<td></td>
</tr>
<tr>
<td>Output power of 15 W (5 V @ 3 A)</td>
<td></td>
</tr>
<tr>
<td>Power transfer efficiency exceed 75%</td>
<td></td>
</tr>
<tr>
<td>Support of FSK communication signals from the medium power transmitter</td>
<td></td>
</tr>
<tr>
<td>Hardware protection of rectifier voltage, output voltage and output current</td>
<td></td>
</tr>
<tr>
<td>Small PCB size (40 mm × 40 mm)</td>
<td></td>
</tr>
<tr>
<td>Open source reference solution with NXP embedded wireless charger software libraries</td>
<td></td>
</tr>
<tr>
<td>USB/adapter power switcher to charge products with wire and wireless with priority</td>
<td></td>
</tr>
<tr>
<td>FreeMASTER tool to enable customization and calibration</td>
<td></td>
</tr>
</tbody>
</table>
WPR1500-LDO

Features:

- High integrated LDO with less external components
- Extreme low BOM cost
- Small PCB size
- Doesn’t need external DC-DC chip and relative circuits
**WPR1500-BUCK**

**Advantage:**

- Efficiency performance is better, can reach 75% with FSL MPTX.
- Can be easily optimized to working at 12.6V/1.2A, 9V/1.67A.
- Small current enduring diode and MOS for rectifier.
Testing Results - Efficiency

Test with FSL MPRX V2.0
ZGAP=5mm

RX Output Power (W)

<table>
<thead>
<tr>
<th>Output Power (W)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.00%</td>
</tr>
<tr>
<td>2</td>
<td>45.00%</td>
</tr>
<tr>
<td>3</td>
<td>50.00%</td>
</tr>
<tr>
<td>4</td>
<td>55.00%</td>
</tr>
<tr>
<td>5</td>
<td>60.00%</td>
</tr>
<tr>
<td>6</td>
<td>65.00%</td>
</tr>
<tr>
<td>7</td>
<td>70.00%</td>
</tr>
<tr>
<td>8</td>
<td>75.00%</td>
</tr>
<tr>
<td>9</td>
<td>80.00%</td>
</tr>
<tr>
<td>10</td>
<td>85.00%</td>
</tr>
</tbody>
</table>
Block Diagram

Medium Power Receiver - HV

- Resonant Circuit
- Rectifier
- DC-DC
- Vout
- Coil
- ASK Modulation
- FSK Demodulation
- Internal LDO
- Vrectifier
- Buck-Enable
- Vout-REF
- Core
- Output Current
- Output Voltage

MWPR1516
Features of WPR1500-HV board

- Compliance with the medium power WPC Qi V1.2 specification;
- Input power (3.5V~20Vac peak) from the transmitter via receiver coil;
- Support of FSK communication signals from the medium power transmitter;
- Hardware protection of rectifier voltage, output voltage and output current;
- Support debugging with IAR/Keil and FreeMASTER tools

- Output power of 15W and adjustable output voltage range from 3.6V to 12V.
- Support Quick Charge 2.0&3.0(Class A).
- Support MTK Pump Express Plus.
QC2.0/3.0 Working Process

At Power up WPR1516 turn-on Q11, D+/D- Shorted;

WPR1516 Start Monitor D+. If stays for at least 1.25s above 0.325 V it disconnect D+/D- and enters in QC2.0/3.0 Mode;

Portable Device then recognizes HVRX as a valid HV support and forcing DC voltages on D+/D- to request a voltage from the WPR1500-HV;

HVDCP outputs 5V,9V,12V as required by Device, apply continuous voltage(for 3.0)

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### Power Supply Output

<table>
<thead>
<tr>
<th>D+</th>
<th>D-</th>
<th>Power Supply Output</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 V</td>
<td>0.6 V</td>
<td>12 V</td>
<td>Class A</td>
</tr>
<tr>
<td>3.3 V</td>
<td>0.6 V</td>
<td>9 V</td>
<td>Class A</td>
</tr>
<tr>
<td>0.6 V</td>
<td>3.3 V</td>
<td>Continuous Mode</td>
<td>Class A/B with ±0.2 V step size</td>
</tr>
<tr>
<td>3.3 V</td>
<td>3.3 V</td>
<td>20 V</td>
<td>Class B</td>
</tr>
<tr>
<td>0.6 V</td>
<td>GND</td>
<td>5 V</td>
<td>Default mode</td>
</tr>
</tbody>
</table>
Pump Express Plus Protocol

The output voltage is controlled via drawing pulse of current from output. WPR1500-HV board detect the current with current sensor.

Command to increase Vout

Logic high current level any value above 250mA;
Logic low current level any value below 130mA;

Command to Decrease Vout
RX board startup normally with QC2.0 test load
QC3.0 Continuous Mode Testing

QC3.0 continuous mode test
MTK Pump Express Plus function testing

Increase Voltage Command

Decrease Voltage Command
Efficiency

HV OUTPUT EFFICIENCY CURVE

- 12V OUT
- 9V OUT

Efficiency vs. Loading (A) graph showing performance data points for different loading levels.
The NX1MP15 is a 15 W universal wireless power front end, capable of supporting A4WP (Alliance for Wireless Power, Rezence), WPC Qi (Wireless Power Consortium inductive power standard), and PMA (Power Matters Alliance) compliant wireless power receivers.

It contains a high-voltage, highly efficient rectifier, integrated LDOs, a DC-to-DC converter, a multi-channel 12-bit ADC, a digital load modulator, four GPIOs and a Fast-Mode I2 C-bus interface.
Application

Resonant Circuits

Rectifier

DC-DC

VOUT

Internal LDO

FSK De-Mod

VREC

NX1MP15

Sample

ASK Modulation

INT

CLAMP

IOUT

GPIO

Sample

Core

5V 1.8V 2.8V

MWPR1516

IIC

Core

5V 1.8V 2.8V

IIC

Rectifier DC-DC Resonant Circuits VOUT Internal LDO FSK De-Mod 5V 1.8V 2.8V Core Coil
SOFTWARE PLATFORM
Software Architecture

End user Layer
- Parameter Calibration & Configuration
- User dedicated code

Application Level
- User Layer
- Application Level
- Processor Layer
- Mid Layer
- APP Layer
- Power Control
- Monitor & Protection & Diagnostic
- Object detection
- Low power mode
- Freemaster

Application
Library

PID Control
Freq. Control
Coils Selection
Touch sensor
LED & Buzzer
Qi Communication
R0
API
Power Control
Monitor & Protection & Diagnostic
Object detection
Low power mode
Freemaster

A. Silver Library or Nevis Silicon level Library

User Layer

Parameter Calibration & Configuration
- User dedicated code

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Parameter Calibration & Configuration
- User dedicated code
SW System diagram
Debugging tool FreeMASTER

System parameters
Calibration/normalization

Real time debugging