Why Not A Wire?
The case for wireless power

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Wireless Power – Replaces A Wire

• Wireless Power is a convenient method of transferring energy from one physical device to a second physical device without contacts

• This allows devices to be powered or batteries to be charged

• It is mostly a convenience issue for consumers and offers

• Different methods or wireless power transfer are available based upon power level requirement and use case
  – Inductive resonant charging
  – Capacitive
  – Solar/Light
  – Vibratory
  – Audio
Wireless Energy Transfer – Overview

Wireless Energy Transfer

Near Field

- Electromagnetic Induction
  - Electrodynamical Induction
  - Electrostatic Induction
    - Inductive coupling
  - Magnetic Resonant Induction

- Electromagnetic Radiation
  - Microwave/RF Power
  - Light/Laser Power

Far Field
Why Do Wireless Charging

• Convenience

• Convenience

• Convenience

• Connector fatigue and failure can be avoided

• Hermetically sealed devices are possible

• Ability to “graze” energy rather than “gorge” means users will have well charged devices when they pick up a device and go
But It’s Not As Efficient As A Wire?!

- Isn’t a wire inherently more efficient than wireless?
- Isn’t a wire 100% efficient?
- What’s the maximum efficiency of wireless power transfer anyway?
Wireless Power System Overview

- Power transmitted through shared magnetic field
  - Transmit coil creates magnetic field
  - Receive coil in proximity converts field into voltage
  - Shielding material on each side directs field
- Power transferred only when needed
  - Transmitter waits until its field has been perturbed
  - Transmitter sends seek energy and waits for a digital response
  - If response is valid, power transfer begins
- Power transferred only at level needed
  - Receiver constantly monitors power received and delivered
  - Transmitter adjusts power sent based on receiver feedback
  - If feedback is lost, power transfer stops
Current Wired charger

Total System efficiency is ~ 60% to 76% TO CHARGER

Total System efficiency is ~ 50% to 64% TO BATTERY

When efficiency of wire (~95%) is included, System efficiency can be ~72% TO CHARGER or even less than 47% TO BATTERY
Current TI Wireless Power EVM System

110VAC/240VAC → 19VDC

AC-DC 60%-80% Efficiency

LV Half Bridge to energize Coil

Transmitter 95% Efficiency

Coil to Coil 89% Efficiency

Receiver 89% Efficiency

Peak Electronics Efficiency 93%

5V 1.0A → Charger

DC System efficiency 75% TO CHARGER

Total System efficiency is 60% TO CHARGER

1. Assuming 80% Adapter efficiency
2. All numbers are typical of a nominal interface gap of 3.7mm, optimal position
3. Peak efficiency shown is shown at 3.5W output power
bqTesla System Efficiency Breakdown

Measured from DC input of Transmitter to DC output of Receiver

- Tx Eff.
- Magnetics Eff.
- Rx Eff.
- System Efficiency

Efficiency (%) vs. Output Power (W)

- TX Eff.
- Magnetics Eff.
- RX Eff.
- System Eff.

Measured from DC input of Transmitter to DC output of Receiver.
- Wireless power in series with existing system
- Adapter sense turns off wireless power when adapter is present
- Termination disables wireless power once charge is complete
RX Architecture – Main Board Charger

- Wired and wireless charger in parallel
- Adapter sense turns off wireless charger when adapter is present
- Highest efficiency solution when observing power transferred to the battery
Direct charging allows the RX to become the battery charger allowing for elimination of a power stage. This allows highest efficiency path and maximal use of thermal budget.
Direct charge solution allow you to turn off the “wired” charger and thus allow you to allocate the thermal budget of the “wired” charger to the “wireless” charger.

Over 10% improvement by going to direct charge
RX Architecture – Output Voltage

- Output Voltage can have a great impact on the efficiency
- Coil and synchronous rectifier $I^2R$ losses are current based

**Efficiency And Output Voltage**
Voltage Regulation Architecture

- **DC Adapter**
  - Flyback
  - One FET Transformer

- **TX**
  - H-Bridge
  - Four FETS

- **WP Transformer**
  - H-Bridge
  - Four FETS

- **RX Sync Rect**
  - Two FETS
  - Inductor

- **Buck Reg**
  - Two FETS
  - Inductor

- **Buck Charger**

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- **DC Adapter**
  - Flyback
  - One FET Transformer

- **TX**
  - H-Bridge
  - Four FETS

- **WP Transformer**
  - H-Bridge
  - Four FETS

- **RX Sync Rect**
  - Dynamic
  - LDO Reg

- **Dynamic LDO Reg**
  - One FET
  - No Inductor

- **Buck Charger**
  - Two FETS
  - Inductor

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**Acts like a Buck**
Architecture Comparison

- Buck Architecture
- TI -- Dynamic LDO

Graph showing the comparison between Buck Architecture and TI -- Dynamic LDO.
Next Gen TI Wireless Power EVM System

110VAC/240VAC

19VDC

AC-DC
60%-80%
Efficiency\(^1\)

LV Half Bridge
to energize Coil

Synchronous FB
Regulator

Peak Electronics
Efficiency 96%

Transmitter
95% Efficiency

Coil to Coil
89% Efficiency

Receiver
95% Efficiency

DC System efficiency 80% TO CHARGER

Total System efficiency is 65\(^1\) TO CHARGER

1. Assuming 80% Adapter efficiency
2. All numbers are typical of a nominal interface gap of 3.7mm, optimal position
3. Peak efficiency shown is shown at 3.5W output power
What Architecture Works Best?

**Battery**

1. All numbers are typical of a nominal interface gap of 3.7mm, optimal position
2. Peak efficiency shown is shown at 3.5W output power

**Diode Bridge**
- Rectifier 95% Efficiency

**HV Half Bridge to energize Coil**
- Transmitter 88% Efficiency

**Direct AC TX**

**Coil to Coil**
- 89% Efficiency

**Direct Charge RX**
- Receiver 93% Efficiency
- Synchronous FB Charger
  - 4.35V 1.0A

**Peak System efficiency 75% TO BATTERY**

**Total System efficiency is > 70% TO BATTERY**

**Texas Instruments**
## Potential Wireless Charging Implementations Compared

<table>
<thead>
<tr>
<th>Wall Adapter</th>
<th>Transmitter</th>
<th>Receiver</th>
<th>Expect Eff. AC to Battery</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Wired Charger</td>
<td>N/A</td>
<td>N/A</td>
<td>~50-65%</td>
<td>As low as 47% when cable eff is included</td>
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<tr>
<td>19V DC Out</td>
<td>Single Coil No Magnet</td>
<td>7V into Charger</td>
<td>52%</td>
<td>Best available Wireless Solution Today</td>
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<tr>
<td>5V DC Out</td>
<td>Single Coil No Magnet</td>
<td>7V into Charger</td>
<td>45%</td>
<td>5V Adapter Design important</td>
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<tr>
<td>19V DC Out</td>
<td>Single Coil No Magnet</td>
<td>Next Gen Direct charge</td>
<td>62%</td>
<td>Direct charge offers higher efficiency</td>
</tr>
<tr>
<td>None</td>
<td>Direct AC TX</td>
<td>Next Gen Direct charge</td>
<td>65-70%</td>
<td>As good as wired?</td>
</tr>
</tbody>
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Thank you