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A Reconfigurable Cross-Connected Wireless Power Transceiver for Bidirectional Device-to-Device Charging

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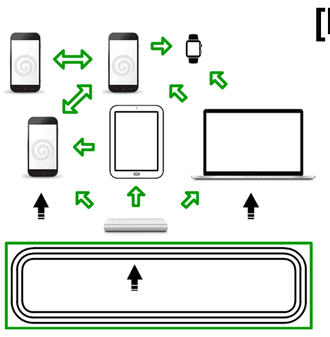
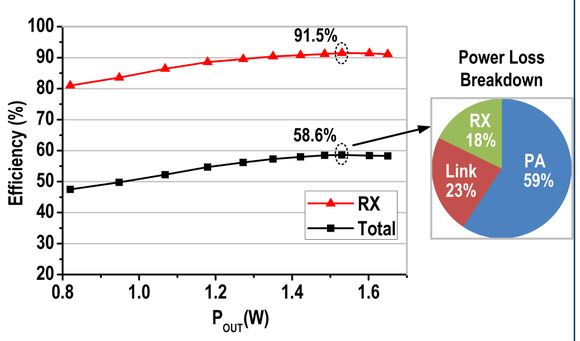
Motivation

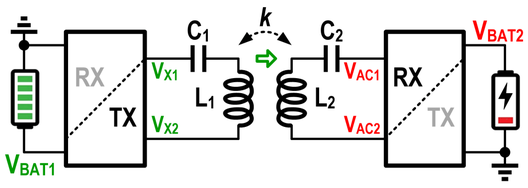
Wireless Power Transfer (WPT):
On the Critical Point of an Explosive Growth!

- **Convenient**
- **Waterproof**
- **Dustproof**
- **Be thinner**

[ISSCC 2017]







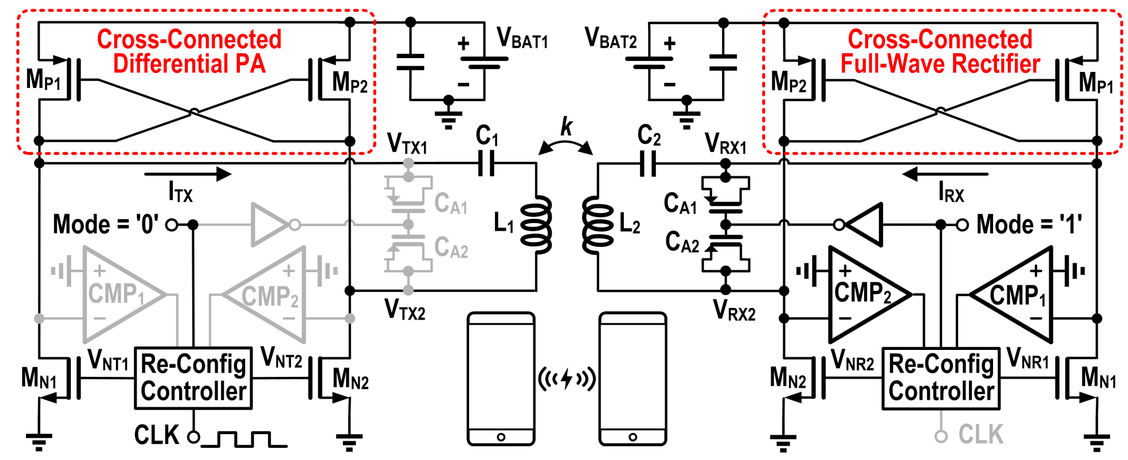
Reconfigurable wireless-power TRX

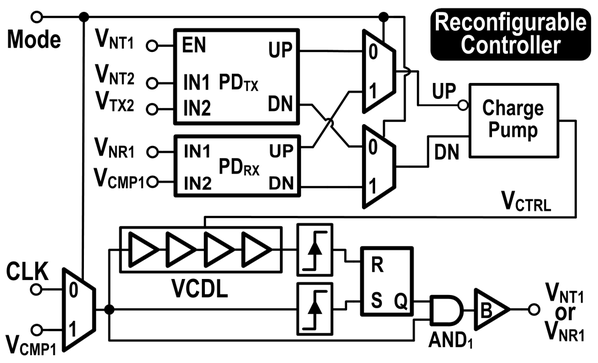
- **Low Efficiency at TX Mode**
- **Low Output Power**
- **Short Transmitting Distance (6mm)**

Proposed Cross-Connected Wireless Power TRX

Reconfigurable Cross-Connected Wireless-Power TRX

Reusing most of the hardware, reducing the gate-driving switching loss.





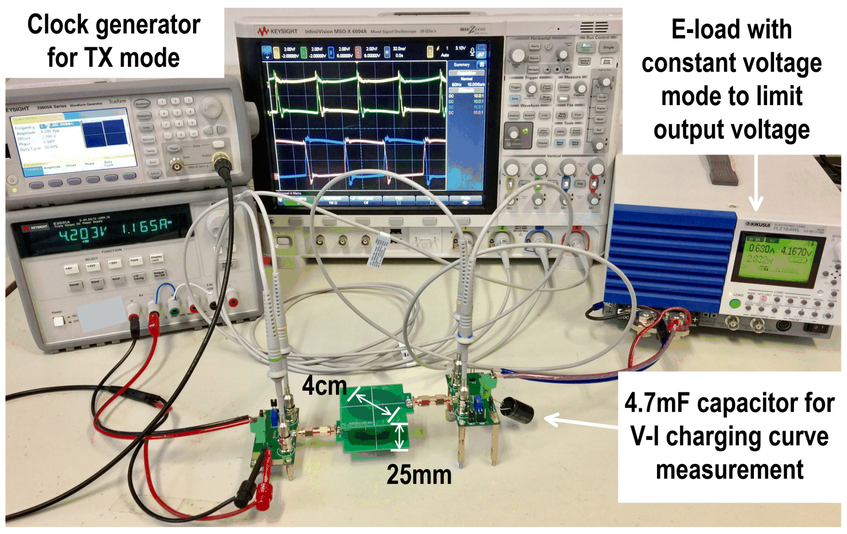
TX Mode

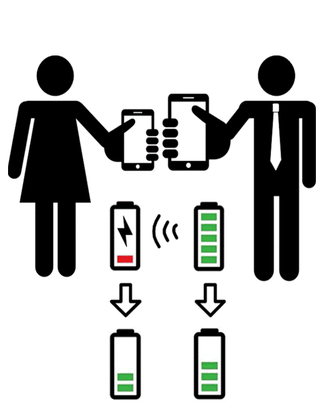
Adaptive Dead-Time Control
Zero-Voltage Switching (ZVS): high efficiency, small transients.

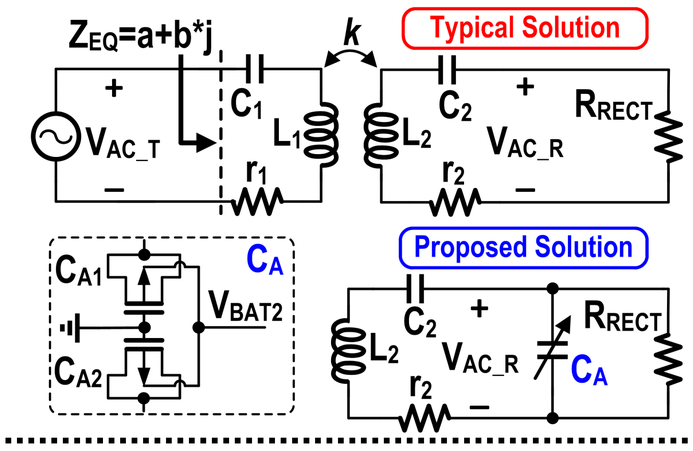
RX Mode

Off-Delay Compensation
Maximizing PCE & P_{OUT}

Design Details







Inductive Load for TX Side

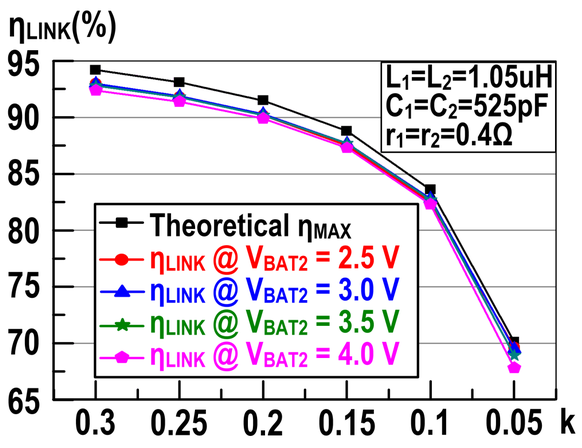
$\omega_{OP} > \omega_{RES}$

$k \in (0, k_c)$, $b>0$ ☑

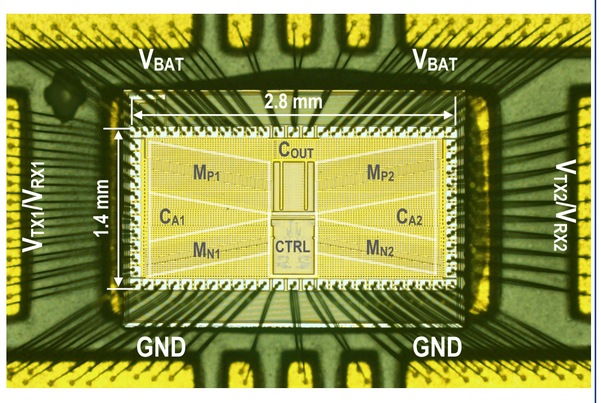
$k \in [k_c, 1)$, $b<0$ ☒

$\omega_{OP} = \omega_{RES}$

$k \in (0,1)$, $b>0$ ☑

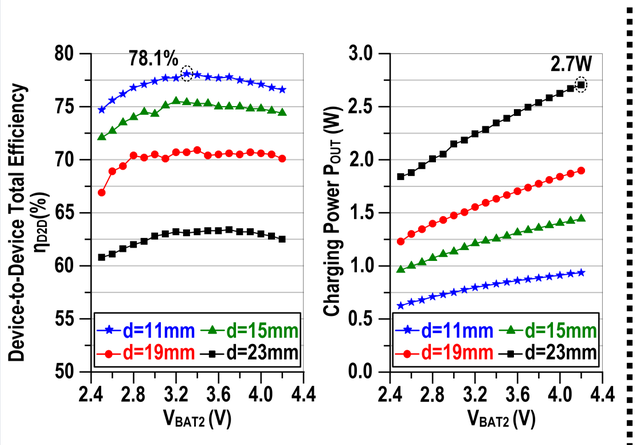


Automatic maximum efficiency-point tracking is achieved.

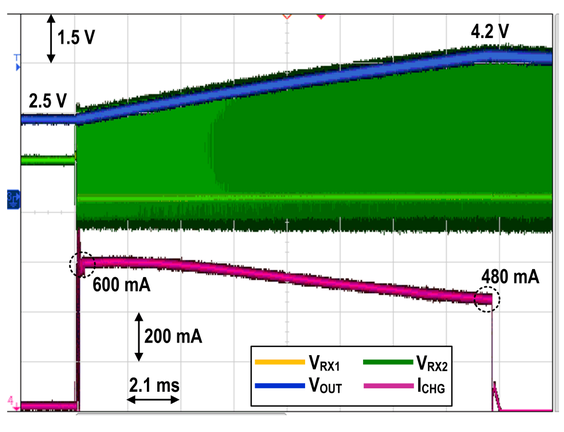


C_{A1} & C_{A2} are placed in the gaps of the power transistors, without increasing the die area.

Experimental Results



D2D total efficiencies and charging power at different output voltages and transmitting distances.



Measured RX AC input voltage, output voltage, and charging current when charging a 4.7mF capacitor.

Comparison with Prior Works

	ISSCC'13 [1]	ISSCC'16 [2]	ESSCIRC'16 [3]	ISSCC'17 [4]	This Work
WPT Direction	Unidirectional	Unidirectional	Unidirectional	Bi-Directional	**Bi-Directional**
Mode	Pad-to-Device	Pad-to-Device	Device-to-Device	Reconf. D2D	**Reconf. D2D**
Process	0.35μm BCD	0.18μm BCD	0.18μm CMOS	0.35μm CMOS	**0.35μm CMOS**
Freq. (MHz)	6.78	0.1-0.3, 6.78	6.78	6.78	**6.78**
$V_{OUT,MAX}$(V)	5	3.5	4.2	4.2	**4.2**
$P_{OUT,MAX}$(W)	6	2.5	0.74	1.65	**2.7**
$\eta_{TOTAL,MAX}$	55%	63%	52.30%	58.60%	**78.10%**
Distance (mm)	NA	NA	19	6	**23**
Area (mm^2)	5.52	5.83	1.2	3.9	**3.92**
Off-Chip Components	5 Diodes 3 Capacitors	1 Inductors 3 Capacitors	2 Inductors 2 Capacitors	1 Capacitor	**1 Capacitor**

The cross-connected wireless-power TRX achieves bi-directional power transfer, high D2D total efficiency, and long transmitting distance with one off-chip capacitor.

[1] J.-H. Choi, et al., "A Resonant Regulating Rectifier (3R) Operating at 6.78 MHz for a 6W Wireless Charger with 86% Efficiency," *ISSCC*, pp. 64-65, Feb. 2013.
[2] J.-T. Hwang, et al., "An All-in-One (Qi, PMA and A4WP) 2.5W Fully Integrated Wireless Battery Charger IC for Wearable Applications" *ISSCC*, pp. 378-379, Feb. 2016.
[3] N. Desai, et al., "A ZVS Resonant Receiver with Maximum Efficiency Tracking for Device-to-Device Wireless Charging," *ESSCIRC*, pp. 313-316, Oct. 2016.
[4] M. Huang, et al., "A Resonant Bidirectional Wireless Power Transceiver with Maximum-Current Charging Mode and 58.6% Battery-to-Battery Efficiency," *ISSCC*, pp. 376-377, Feb. 2017.

KEY CONTRIBUTIONS

1. Cross-Connected structure in the differential class D PA.
2. Reconfigurable controller for optimal switching timing in TX/RX.
3. Variable capacitor for inductive load in TX mode.
4. Automatically peak link efficiency point tracking.

Acknowledgement/Contact

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