Scalable Energy Harvesting from the NFC Band: A 13.56 MHz Active Rectifier Adaptable for Low-Power Systems

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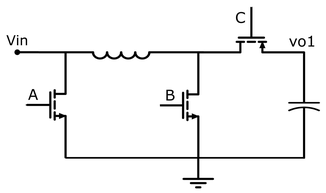
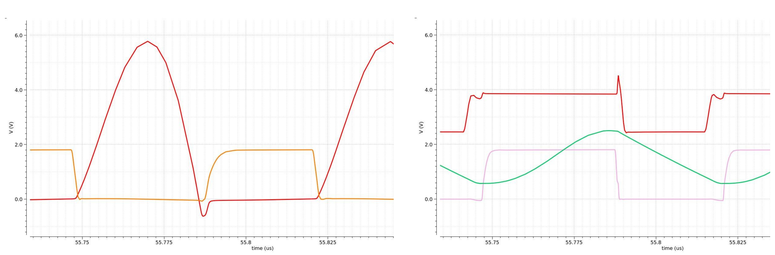
Motivation

- Charge and power battery-powered biomedical devices at medium to long range with high efficiency
- Operate at 13.56 MHz (NFC Band)
- Would be paired with a low power NFC listener IC that performs handshake

Switching Scheme

- Three main switches in the circuit
  - A (rectifier), B & C (boost converter)
- A turns on when voltage is less than 0V
- B cuts off the inductor at its peak current
- C turns on immediately after B turns off to charge capacitive load





Input Signal (Red) and Signal A (Orange) Plotted vs. Time. A turns on in negative voltages to rectify the input.

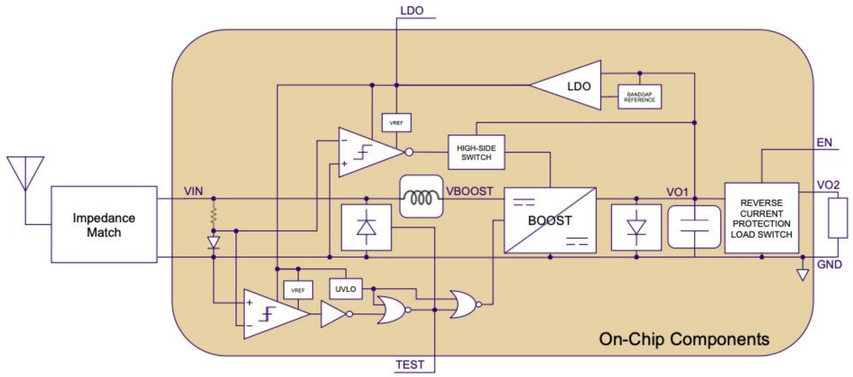
Inductor Current (Green), Signal B (Pink) & Signal C (Red) Plotted vs. Time. B turns off as current peaks, maximizing inductor voltage, then shorted to vo1 by C.

Power Conversion Efficiency

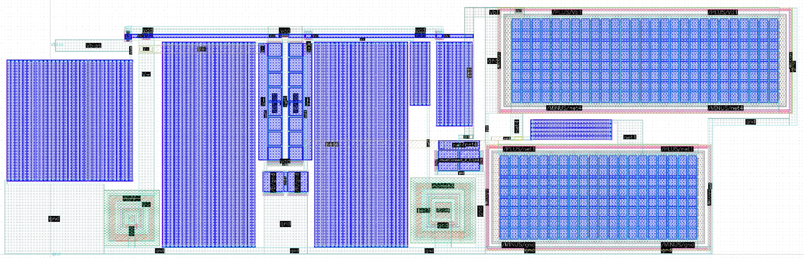
Input Power (mW)	Efficiency Specification	Schematic Measurements
25	45%	62.7%
50	50%	66.3%
100	60%	70.9%
200	70%	72.2%
400	80%	74.5%
500	85%	76.8%

Comparing to State of the Art							
	TVLSI '18 [1]	JSSC '19 [2]	JSSC '20 [3]	TCAS-I '20 [4]	TBCAS '21 [5]	JSSC '23 [6]	This Work
Technology	350nm	180nm	180nm	180nm	180nm	180nm	180nm
Frequency	13.56MHz	13.56MHz	1-10MHz	40.68MHz	6.78MHz	40.68MHz	13.56MHz
Peak PCE	84.6-86.1%	85.0-94.1%	84.4-91.5%	70.7-80.9%	92.7-95.0%	81.9-86.0%	76.8%

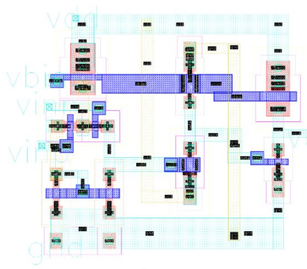
Block Diagram



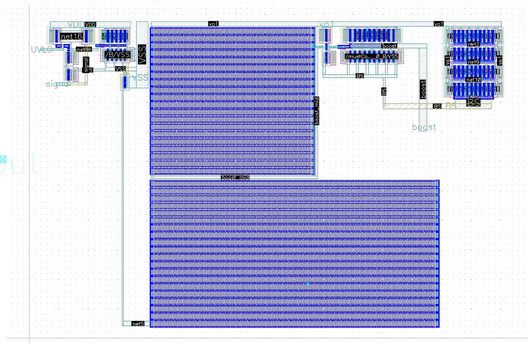
Layout Parts



Bandgap Voltage Reference

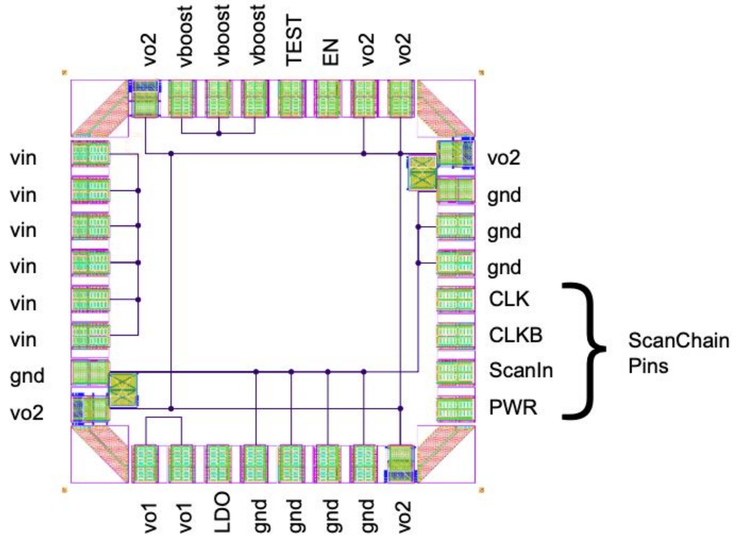


Comparator



High-Side Switch

Pinout



Testing Our Chip

- Testing Setup:
  - Function Generator and oscilloscope to measure efficiency
- VNA will be used for impedance matching
- PCB coils will be designed to measure WPT
- Most function generators can deliver 250 mW. Optionally, amplifier can be used to transmit up to 1 W

Future Work and References

- Continue to make design more robust across input power levels
- Optimization of top-level layout
- Test final result once returned from fabrication facility for real-world PCE

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[3] R. Erfani, F. Marefat, S. Nag, and P. Mohseni, "A 1-10-mhz frequency-aware cmos active rectifier with dual-loop adaptive delay compensation and > 230mw output power for capacitively powered biomedical implants," IEEE Journal of Solid-State Circuits, vol. 55, no. 3, pp. 756–766, 2020.
[4] L. Cheng, X. Ge, L. Hu, Y. Yao, W.-H. Ki, and C.-Y. Tsui, "A 40.68-mhz active rectifier with hybrid adaptive on/off delay-compensation scheme for biomedical implantable devices," IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 67, no. 2, pp. 516–525, 2020.
[5]G. Namgoong, E. Choi, W. Park, B. Lee, H. Park, H. Ma, and F. Bien, "A 6.78 mhz, 95.0 peak efficiency monolithic two-dimensional calibrated active rectifier for wirelessly powered implantable biomedical devices," IEEE Transactions on Biomedical Circuits and Systems, vol. 15, no. 3, pp. 509–521, 2021.
[6] Z. Luo, J. Liu, and H. Lee, "A 40.68-mhz active rectifier with cycle-based on-/off-delay compensation for high-current biomedical implants," IEEE Journal of Solid-State Circuits, vol. 58, no. 2, pp. 345–356, 2023.

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