جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

TECHNOLOGY OPPORTUNITY

Innovative High-Voltage Charge Pump

For a smaller footprint in consumer electronics and other devices

The high-voltage charge pump represents an important advance in reducing the footprint of portable and other electronic devices. Its innovative design enables the use of high-density, low-voltage pumping capacitors, which require significantly less area than the high-voltage pumping capacitors of conventional designs. This innovative charge pump can be implemented using conventional complementary metal-oxide semiconductor (CMOS) technology, which makes it cost-competitive and simplifies integration with other devices on a single chip. The technology has been proven by fabrication and testing and has achieved output voltages up to 51V.

Originally designed to drive microelectromechanical system (MEMS) gyroscopes, the technology can be applied to a wide array of MEMS electrostatic devices or any other devices requiring high voltage. The MEMS market is expanding rapidly, and this high-voltage charge pump helps miniaturize the total electronics package in portable consumer devices, computer displays, printers, automotive sensors, and biomedical systems.

Benefits

- **Reduces overall electronics footprint:** Uses high-density, low-voltage capacitors, significantly reducing the overall size of the charge pump
- **Integrates easily at a competitive cost:** Uses commercial CMOS technology to provide an easy-to-integrate, cost-competitive charge pump
- **Achieves high voltage output:** Requires only 6V input voltage to provide up to 51V of output voltage
- **Offers proven results:** Has been prototyped and tested in the lab

Applications

- Cell phones and smart phones
- Electronic notebooks and tablets
- Computer displays
- Disk drives
- Ink-jet printer components
- Biomedical systems
- Automotive air bags and sensors
- Gyroscopes, radiofrequency (RF) MEMS, accelerometers, varactors

Why It Is Better

The KAUST technology offers an important advance for the miniaturization of consumer and mobile electronic devices. It uses low-voltage, high-density capacitors, thereby reducing the overall size of the charge pump. Cell phones, smart phones, portable computers, tablets, and many other electronic devices are increasingly using gyroscopes and other MEMS devices to enhance their functionality, and these applications require the use of charge pump circuits.

Opportunity

This technology is part of KAUST's technology commercialization program that seeks to stimulate development and commercial use of KAUST-developed technologies. Opportunities exist for joint development, patent licensing, or other mutually beneficial relationships.

For More Information

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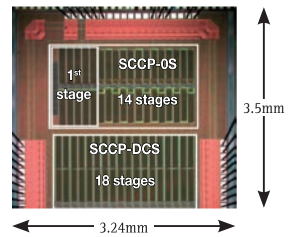
Technology Details

High-voltage charge pumps take a low-voltage input and increase that voltage to a higher amount needed to power electronic devices. The KAUST high-voltage charge pump has an input voltage of 6V and generates an output of up to 51V. By using low-voltage capacitors, which require less space than high-voltage capacitors, this innovation reduces the overall area required to implement the charge pump.

How It Works

Typically, charge pump designs use clock and inverse-clock signals to create an additive voltage effect over a series of capacitor stages. In this scenario, the voltage across the capacitor increases in each stage, which necessitates the use of high-voltage capacitors. The KAUST innovation incorporates a special clocking scheme that limits the voltage across each capacitor at one low level, which allows for low-voltage capacitors to be used for all stages. Only the output capacitor stage needs to be a high-voltage capacitor, which can be off-chip.



Die photo of the two charge pumps

Reference		Max. V_{OUT}	Number of stages	Supply voltage (V)	Load current	Technology	Switching frequency (MHz)	Pumping capacitor (pF)	Max. cap. voltage (V)[7]	Active devices
KAUST Series-Capacitor Charge Pump	with Ohmic Switch (SCCP-OS)	42.8	14	6	10μA @ 10%drop	0.6μm CMOS	2	50	6	PMOS only[8]
	with Diode-Connected Switch (SCCP-DCS)	51	18	6	4μA @ 10%drop	0.6μm CMOS	.5	50	6	PMOS only
Hoque et al.[1]		19.6	6	3.3	20μA	0.35μm SOI CMOS	4	16	16.3	Diodes only
Hoque et al.[2]		26.9	9	3.3	40μA	0.35μm SOI CMOS	4	30	23.6	PMOS-NMOS
Yang et al.[3]		39	3	5	2mA	0.7μm-100V CMOS	1	Not specified	39	PMOS-NMOS
Khouri et al.[4]		8.7	4	2.5	360μA	0.13μm CMOS	20	37	6.3	NMOS only
Innocent et al.[5]		14.8	10	1.8	0.7μA	0.18μm CMOS	50	10	13	PMOS-NMOS
Ker et al.[6]		28	12	2.5	2μA @ 20%drop	0.25μm CMOS w/ polySi diodes	1	Not specified	25.5	Diodes only

1. M. Hoque, T. McNutt, J. Zhang, A. Mantooth, and M. Mojarradi, "A high-voltage Dickson charge pump in SOI CMOS," Proceedings of the IEEE Custom Integrated Circuits Conference, 2003, pp. 493–496.
2. M. Hoque, T. Ahmad, T. McNutt, A. Mantooth, and M. Mojarradi, "Design technique of an on-chip, high-voltage charge pump in SOI," IEEE International Symposium on Circuits and Systems (ISCAS), 2005, vol. 1, pp. 133–136.
3. L.-S. Yang, T.-J. Liang, H.-C. Lee, and J.-F. Chen, "Novel high step-up DC-DC converter with coupled-inductor and voltage-doubler circuits," IEEE Transactions on Industrial Electronics, Sept. 2011, vol. 58, no. 9, pp. 4196–4206.
4. O. Khouri, S. Gregori, A. Cabrini, R. Micheloni, and G. Torelli, "Improved charge pump for flash memory applications in triple well CMOS technology," Proceedings of the IEEE International Symposium on Industrial Electronics (ISIE), 2002, vol. 4, pp. 1322–1326.
5. M. Innocent, P. Wambacq, S. Donnay, W. Sansen, and H. De Man, "A linear high-voltage charge pump for MEMS applications in 0.18m CMOS technology," Proceedings of the 29th European Solid-State Circuits Conference (ESSCIRC), 2003, pp. 457–460.
6. M.-D. Ker and S.-L. Chen, "On-chip high-voltage charge pump circuit in standard CMOS processes with polysilicon diodes," Asian Solid-State Circuits Conference, 2005, pp. 157–160.
7. Maximum voltage across pumping capacitors is $V_{OUT} - V_{IN}$ in most cases, except for the proposed designs.
8. Except for the first stage clock-level shifting circuit, where NMOS transistors are used.

IP Protection

KAUST has several patents pending for this technology.