Robert Bosch Center for Power Electronics
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High Vin SC Converters and Supporting Circuits for Power on Chip Applications

PwrSoC 2016, Madrid

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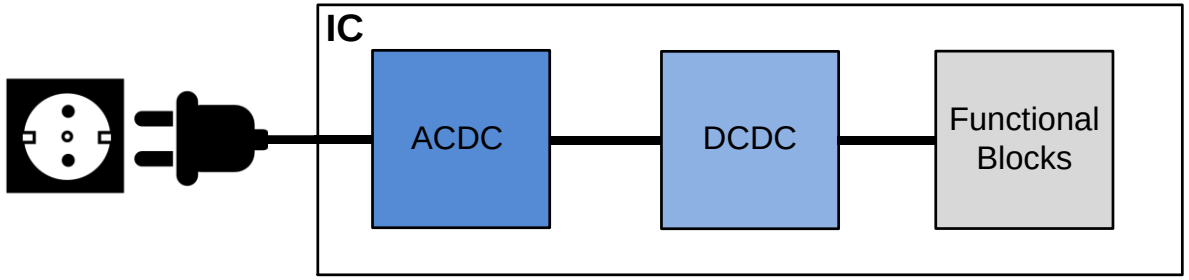
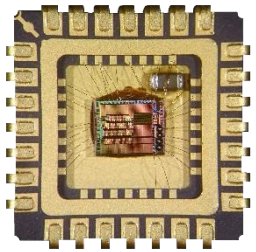
Fully Integrated Power Supply



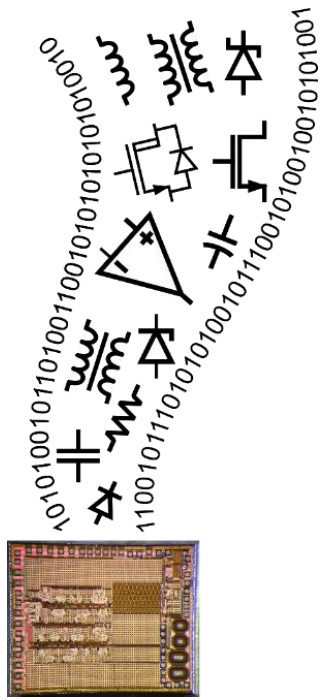
ACDC

Micro power supply
an on chip mains adapter
230Vrms to 3.3Vdc



DCDC

Fully integrated power management without external components

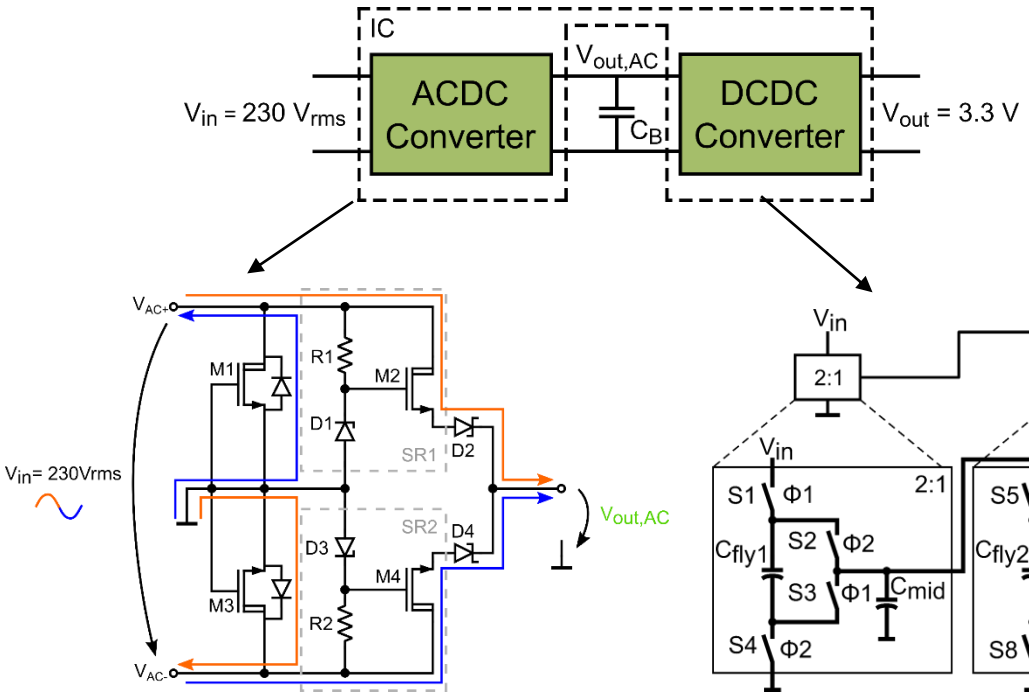


Function

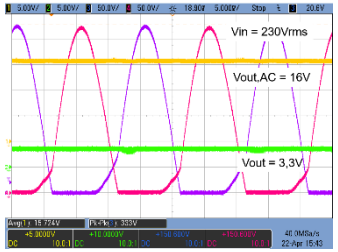
A 120/230 Vrms-to-3.3 V Micro Power Supply

Highlights Fully integrated ACDC and DCDC converter with 3mW output power and one external SMD cap

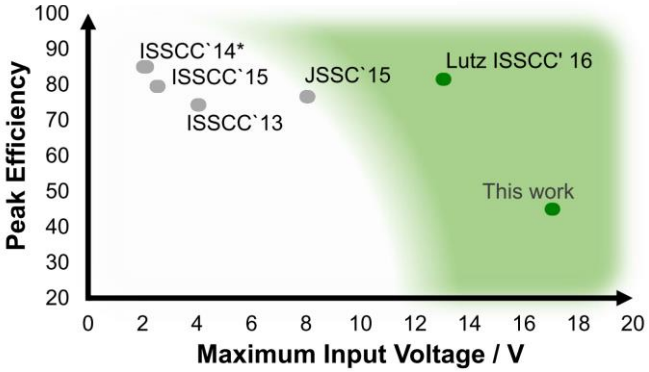
Block diagram



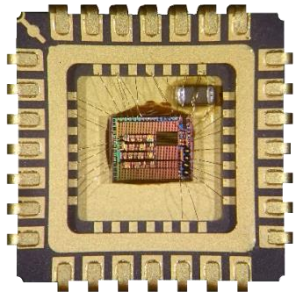
Measurement



State of the art



Micro Power Supply (PSiP)



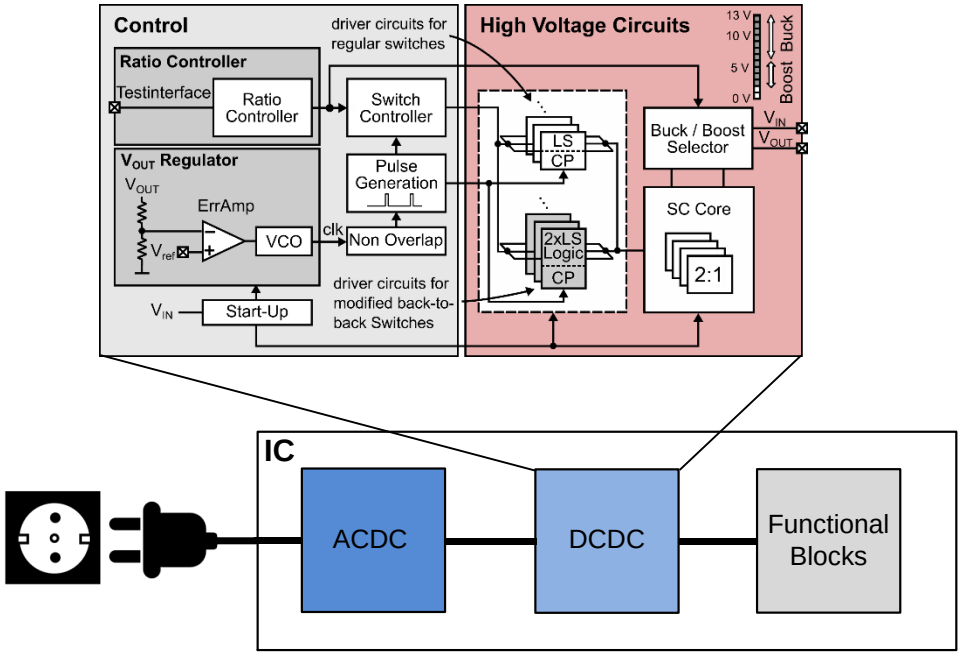
Publications IEEE ESSCIRC 2016

Goal Micro Power Supply as low power (~10mW) on-chip mains adapter
→ elimination of bulky power supplies, alternative to energy harvesting

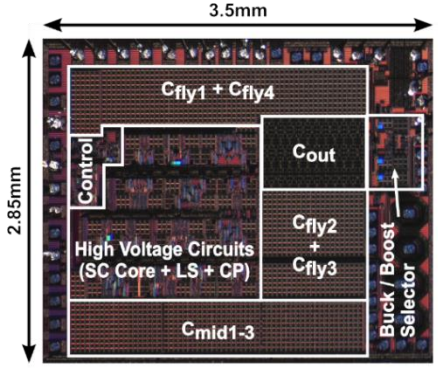
Fully Integrated 2-to-13V-Input SC Converter

Highlights World's first fully integrated capacitive DCDC converter with 13V input, buck-boost mode, novel area efficient back-to-back switch, η_{max}>80%

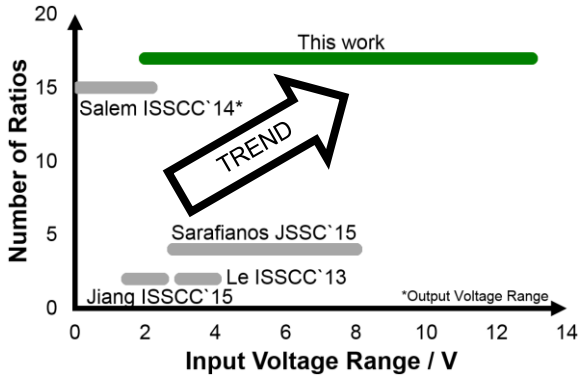
Block diagram



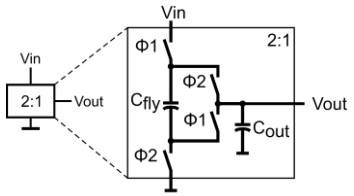
Test chip with 3.64nF (MIM)



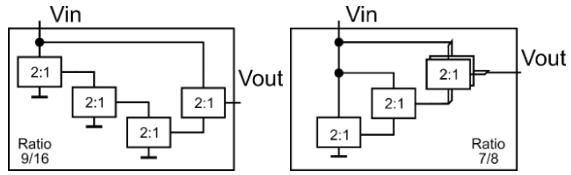
State of the art



Core SC cell



Example configurations (ratios)

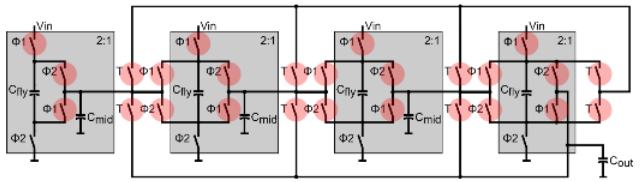


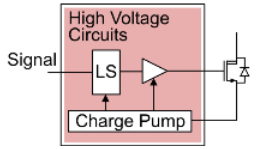
Goal Part of ACDC converter as low power (~10mW) on-chip mains adapter → elimination of bulky power supplies, alternative to energy harvesting

Publications IEEE ISSCC 2016

High-Voltage Challenges

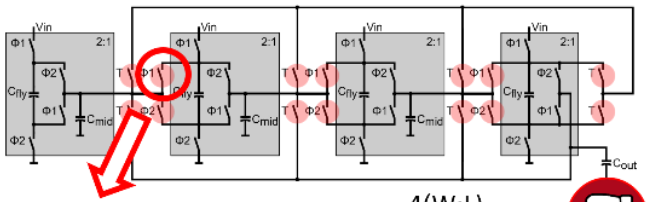
High-Voltage Challenges: Switch Ctrl



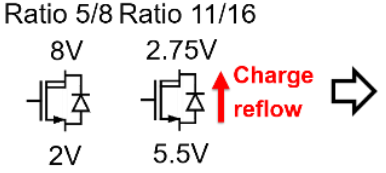


- No common switch signals possible
- Low power and area efficient design is crucial

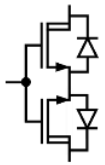
High-Voltage Challenges: Body Diode



Ratio 5/8 Ratio 11/16

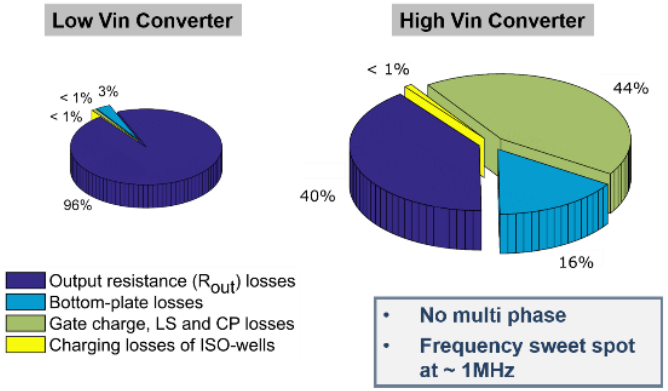


4(W·L)



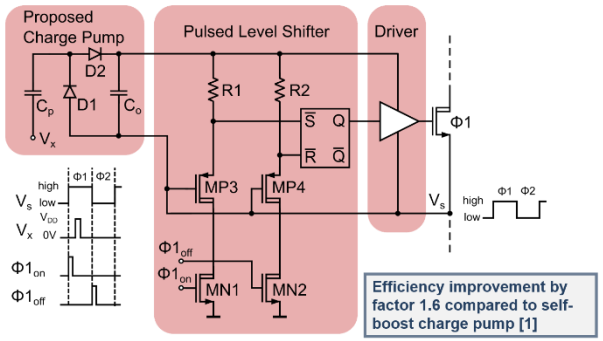
4x gate charge losses

Loss Brake Down SC Converters



- No multi phase
- Frequency sweet spot at ~ 1MHz

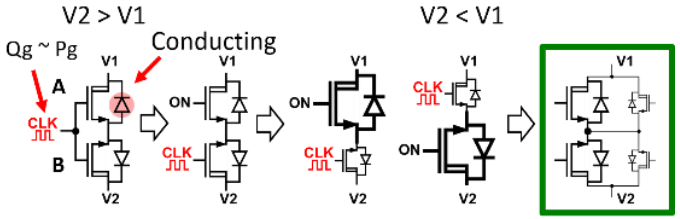
High-Voltage Circuits – Proposed Charge Pump



Efficiency improvement by factor 1.6 compared to self-boost charge pump [1]

[1] Shihong Park and T. M. Jahns, "A self-boost charge pump topology for a gate drive high-side power supply," in *IEEE Transactions on Power Electronics*, vol. 20, no. 2, pp. 300-307, March 2005.

Improved Back-to-Back Switch

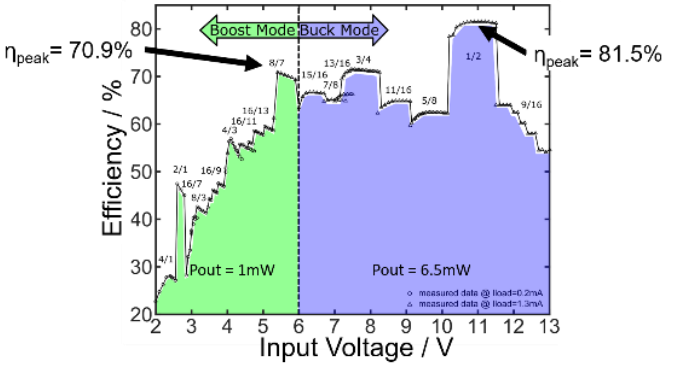


Losses (Pg)	4x	2x	~1x	~1x	~1x
CP size	4x	2x	~1x	~1x	~1x
Rdson	1x	1x	1x	1x	1x

Gate charge losses like a single transistor

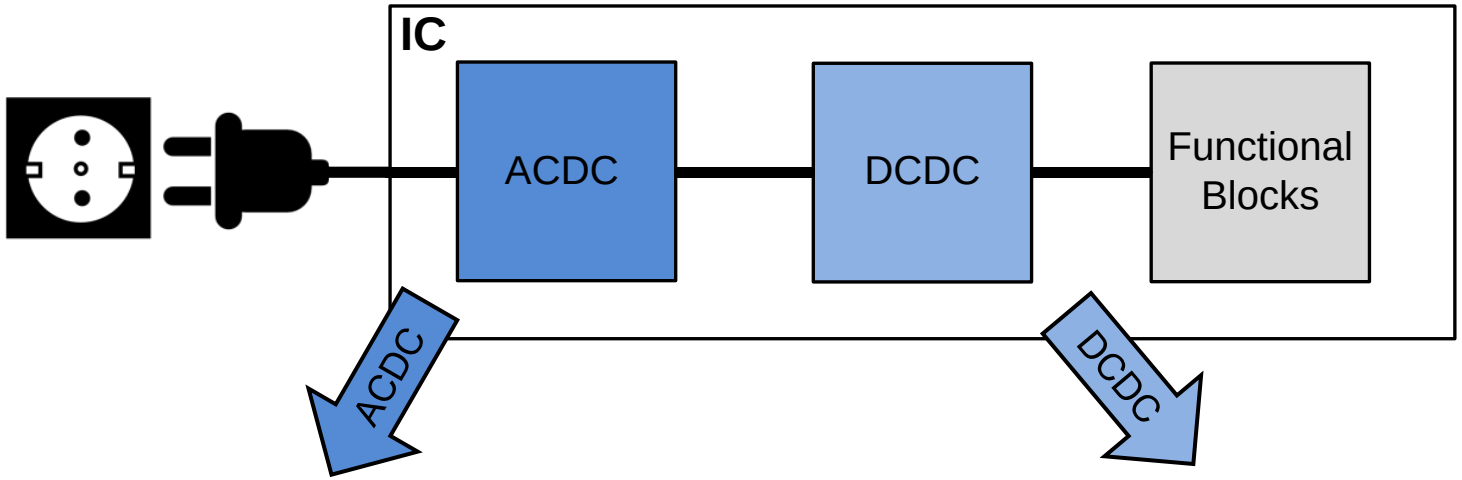
- Gate charge loss reduction by 70%
- Area reduction combined with CP up to 75%

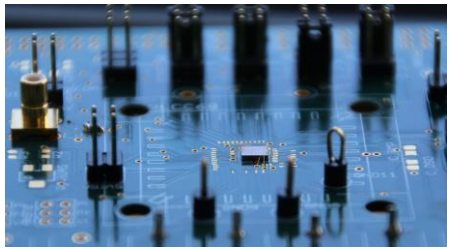
Measured Efficiency



Wide input voltage range and buck boost mode

High Vin SC Converters





Performance Comparison

	Tamez ESSCIRC´14	Meyvaert ESSCIRC´2012	This work
Technology	0.13 µm	0.35 µm	**0.35 µm**
V_{in}	120 Vrms	120/230 Vrms	**120/230 Vrms**
V_{out}	4 V	3.3 V	**3.3 V**
ext. components	-	1x SMD cap	**1x SMD cap**
Chip Size	3.5 mm^2	6 mm^2	**7.7 mm^2**
$P_{out,max}$	1.5 µW	208 µW	**3 mW**
Power Density	0.43 $\mu W/mm^2$	34.6 $\mu W/mm^2$	**390 $\mu W/mm^2$**

Performance Comparison

	Salem ISSCC´14	Sarafianos JSSC´15	Le ISSCC´13	Jiang ISSCC´15	This Work
Technology	0.25µm CMOS	90nm CMOS	65nm CMOS	65nm CMOS	0.35µm HVCMOS
Conversion ratios	15 (4bit)	1/2, 1/3, 1/4 1/5	1/3, 2/5	1/3, 1/4	**8 buck + 9 boost**
Efficiency (peak)	85%	76.6%	74.3%	79.5%	**81.5%**
Input voltage	2.5V	2.8-8V	3-4V	1.5-2.5V	**2-13V**
Output voltage	0.1-2.18V	1.2V	1V	0.4-0.7V	5V
Buck-boost mode	no	no	no	no	**yes**
Output power	4.6mW	50mW	121mW*	26mW	**10mW (buck)**
Total cap amount	3nF	5nF	3.88nF	not reported	3.64nF
Active area / mm²	4.645	not reported	0.64	0.23	6.8

*calculated

Prototype of Proposed Micro Power Supply