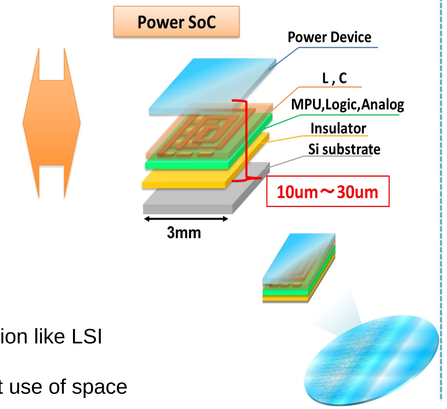
Transient response of Field Programmable Power Supply Array based on power SoC

Madoka Higashida, Seiya Abe, Satoshi Matsumoto
Kyushu Institute of Technology

Introduction

Market demand of power supply
- Reduction in Size and Weight
- High efficiency
- High speed response
- Reduction in Cost

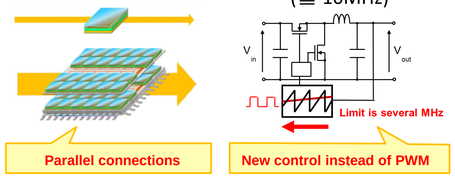


➢ Power SoC's Advantages

1. Size and weight reduction
2. High efficiency
3. Cost reduction ⇒Mass production like LSI
4. High performance
   ⇒Stable operation and efficient use of space

➢ Challenges and Approaches

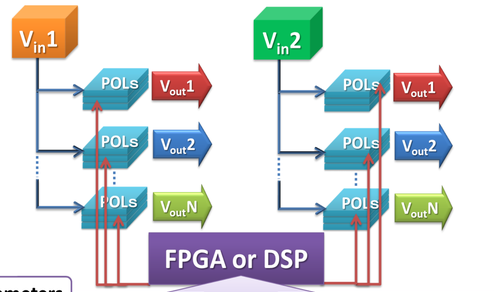
①Small power capacity ②High-frequency switching (≧ 10MHz)



✓ **Power SoC based on parallel connections of many dc-dc converters**

Block diagram and Control method

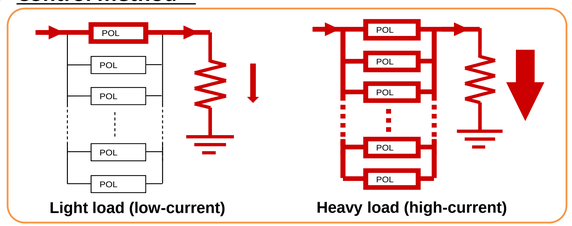
➢ Block diagram[1]



4parameters — Didital Code: Number of Vout・Vin / Each maximum Iout / Each Vout

✓ Only rewriting of digital code , It can be multiple input and output

➢ Control method[2]



Switching number N in response to output current

Formula

○Buck converter

$$V_{out} = DV_{in} - \frac{r}{N}I$$

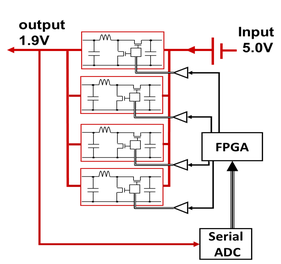
○Boost converter

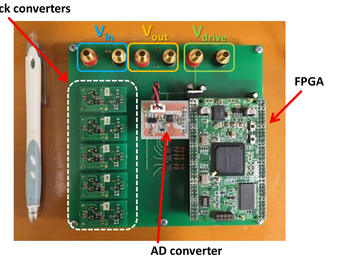
$$V_{out} = \frac{1}{1-D}V_{in} - \frac{r}{N}I$$

D: Duty ratio
r : Internal resistance
N: Number of DC-DC converter
I : Output Current

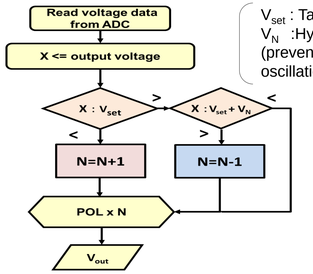
Circuit configuration and Control algorithm

➢ Circuit configuration





➢ Control agorithm

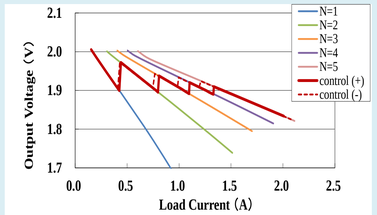


V_{set} : Target Voltage
V_N :Hysteresis (preventing oscillation)

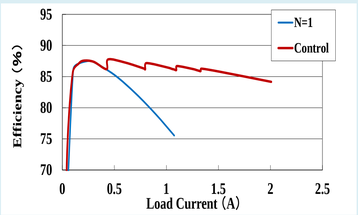
Results

➢ Experiments

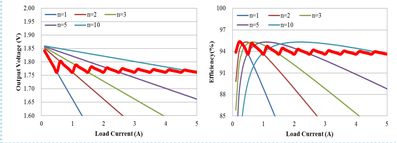
◆ Load characteristic



◆ Efficiency characteristic

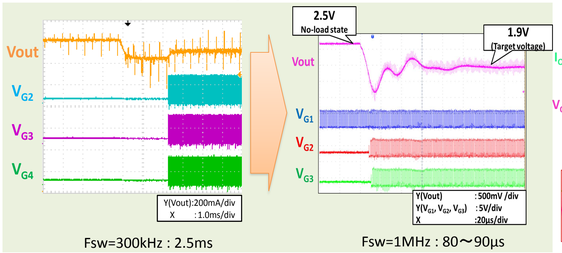


➢ Simulations

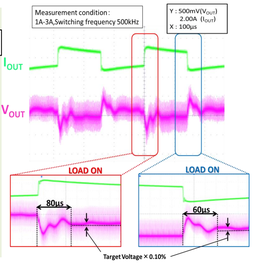


✓ **Obtained a constant output voltage**
✓ **Keeping high efficiency over wide range**

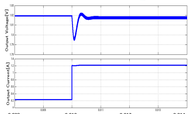
➢ Transient response of experiments



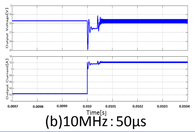
Fsw=300kHz : 2.5ms　　Fsw=1MHz : 80～90μs



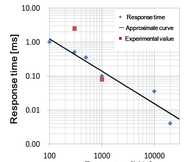
➢ Simulation by Matlab Simulink



(a)300kHz : 1.0ms



(b)10MHz : 50μs



✓ **Transient response is dependent on switching frequency**

Conclusion

✓Full digital control ⇒ Rewriting 4 digital code without adjustment
✓**High-speed response realized through increasing switching frequency**

References

[1] M. Higashida et al., EPE'15 ECCE Europe, 0365,2015.
[2] T. Yamamoto et al. IEEE PEDS 2013, pp.109-112, 2013.

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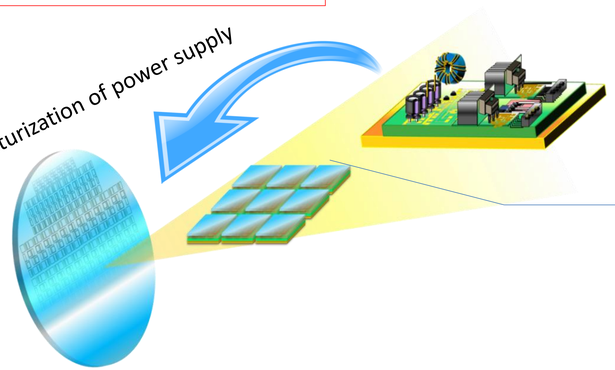
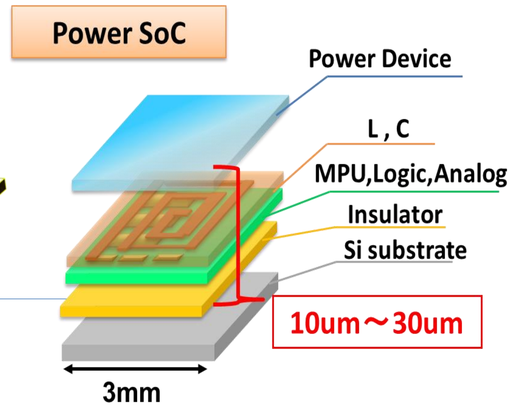
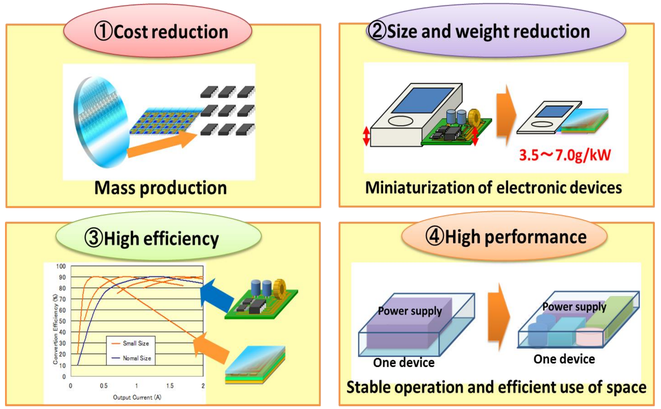
Miniaturization of power supply



Ultimate miniaturization = One chip POL

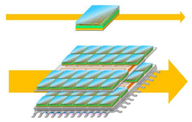


➢Power SoC's Advantages



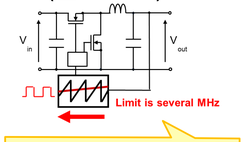
➢Challenges and Approaches

①Small power capacity



Parallel connections

②High-frequency switching (≧ 10MHz)

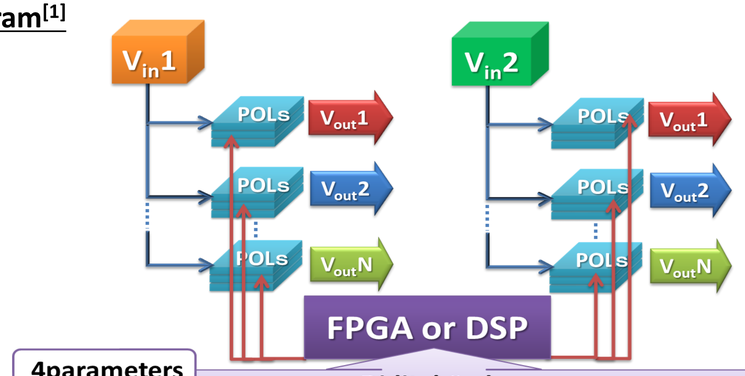


New control instead of PWM

✓Power SoC based on parallel connections of many dc-dc converters

Block diagram and Control method

➢Block diagram[1]



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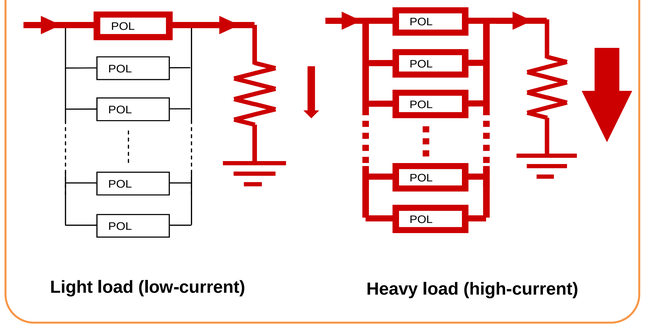
➢Control method[2]



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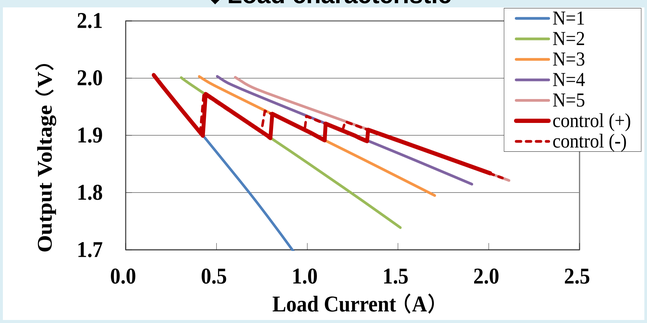
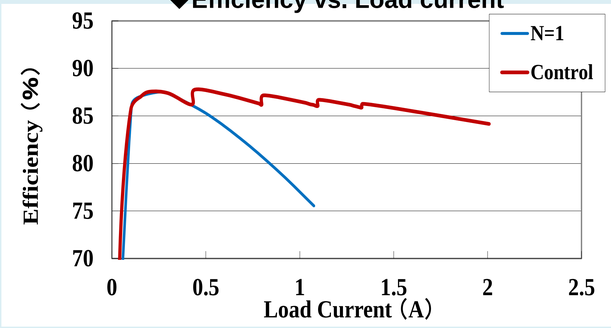


◆Efficiency vs. Load current



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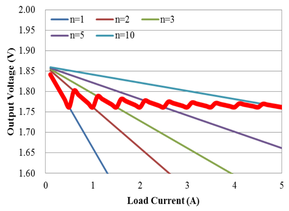

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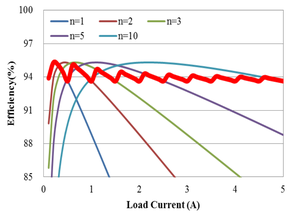
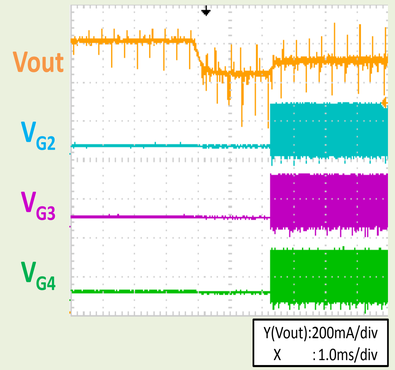
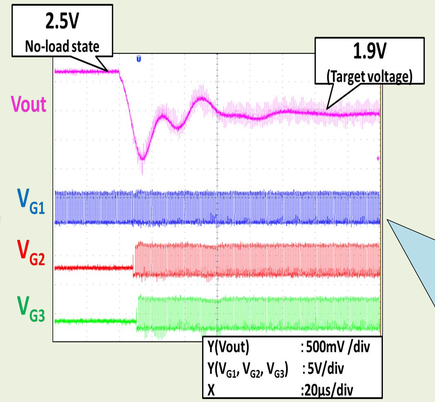


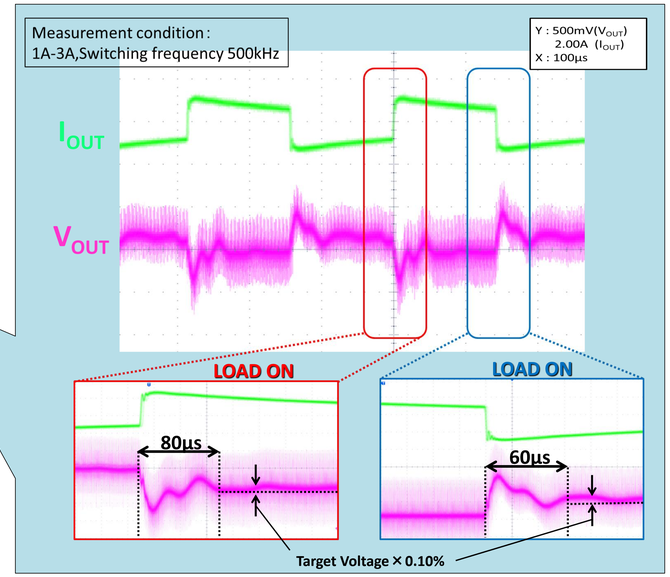
➢Experimental results of transient response



Fsw=300kHz : 2.5ms



Fsw=1MHz : 80µs



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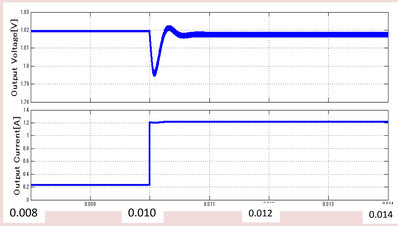

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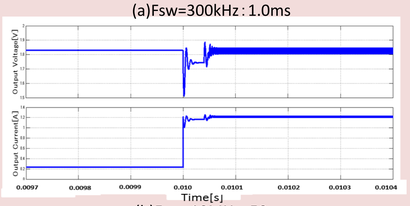
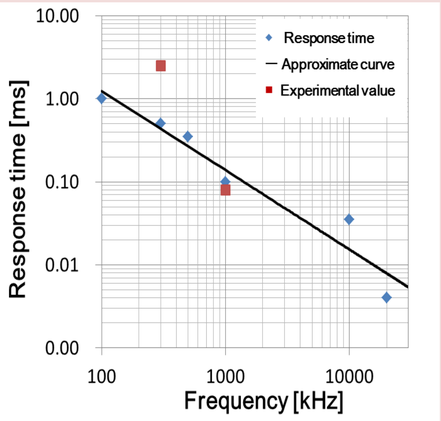


(b)Fsw=10MHz : 50µs



✓Obtained a constant output voltage
✓Keeping high efficiency over wide range

✓Transient response time is dependent on switching frequency