PWM Controlled High-Frequency Current-Mode Resonant DC-DC Converter

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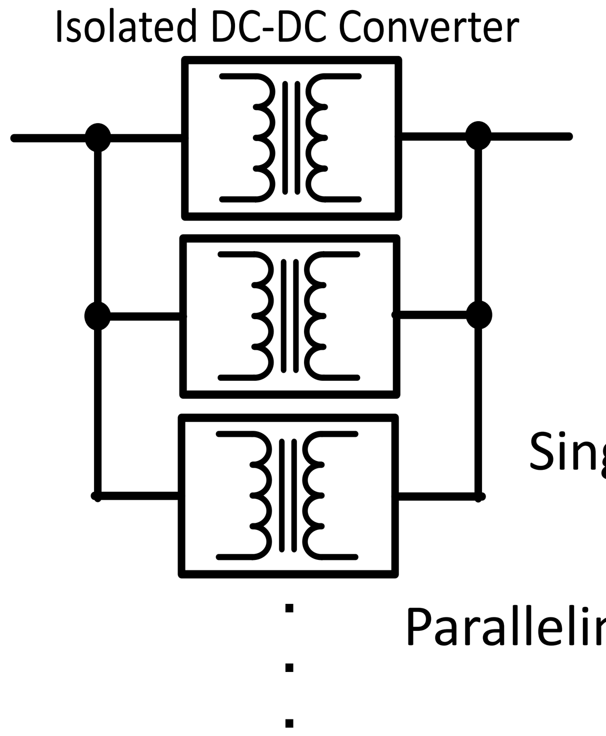
Background

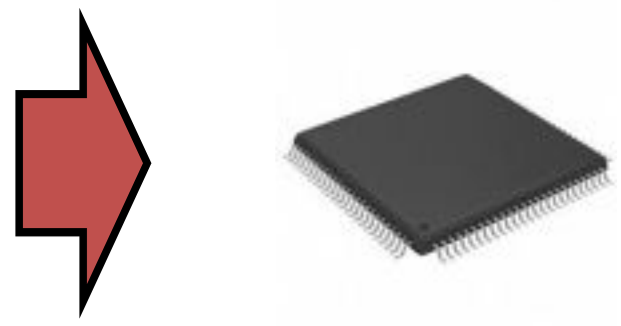
Purpose of the work

Developing high efficiency isolated micro DC-DC converter.

Key Technique :

- Parallel structure (1/n internal resistance)
- Current resonant (ZVS)
- PWM control (Constant f_s)





Single converter output resistance loss

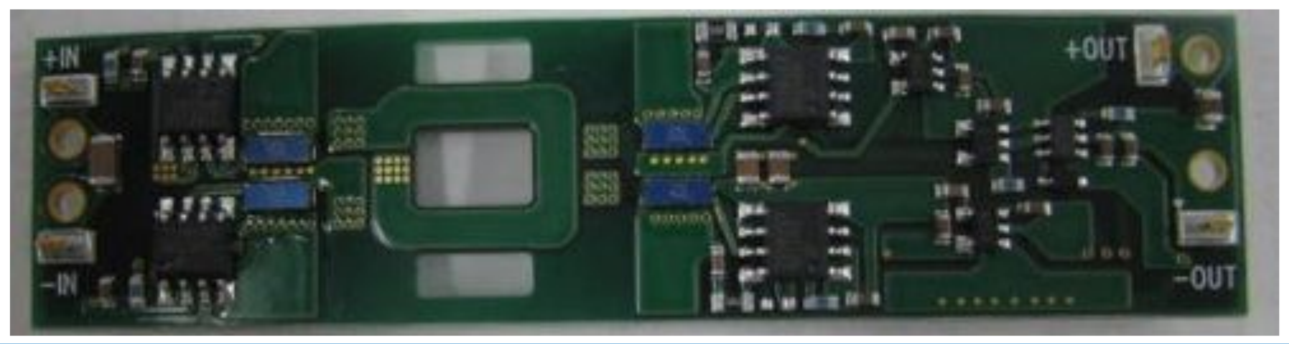
$$P_{loss} = R_o I_o^2$$

Paralleling converters output resistance loss

$$P_{loss\_p} = R_o \left(\frac{I_o}{n}\right)^2 \times n = \frac{1}{n} R_o I_o^2$$

Previous work: 5MHz current-mode resonant DC-DC converter (without control)

- Input/output voltage of 48V/12V
- Power rating of 120W
- Efficiency of 92%
- Power density of 14W/cc
- GaN-FET were utilized



Height: 0.8 inch, Width: 3.2 inch, Thickness: 0.3 inch

Reference: Ken Matsuura, Hiroshige Yanagi, Satoshi Tomioka, and Tamotsu Ninomiya "Power-Density Development of A 5MHz Switching DC-DC Converter," IEEE APEC 2012

What is the best control technique?

Commonly, current-mode resonant converter is controlled by PFM which variable switching frequency.

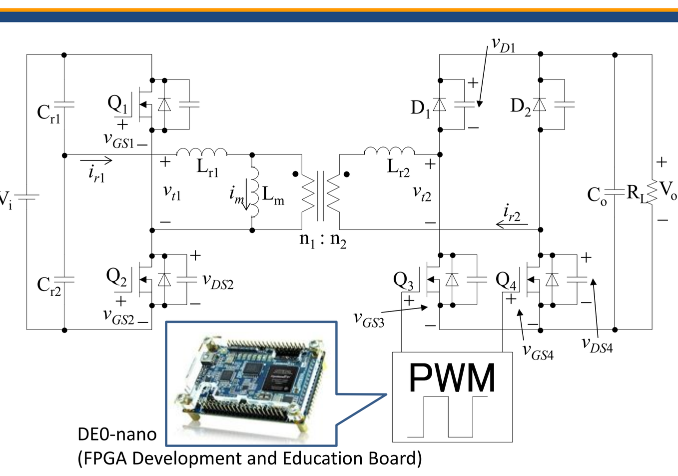
PFM (Pulsed Frequency Modulation)   Cons.

- Designing a noise filter is difficult because of variable switching frequency.
- Beat phenomenon will be occurred when each converter's switching frequency differ in parallel structure.

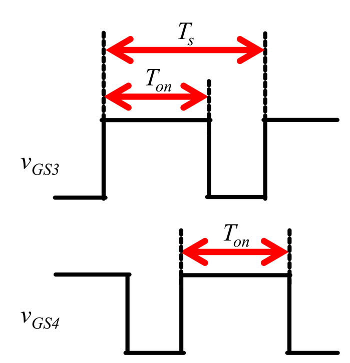
PWM (Pulsed Width Modulation)

- Designing a noise filter is easy because of fixed switching frequency.
- Fixed switching frequency (Beat phenomenon won't be occurred)

Proposed Circuit with FPGA controller



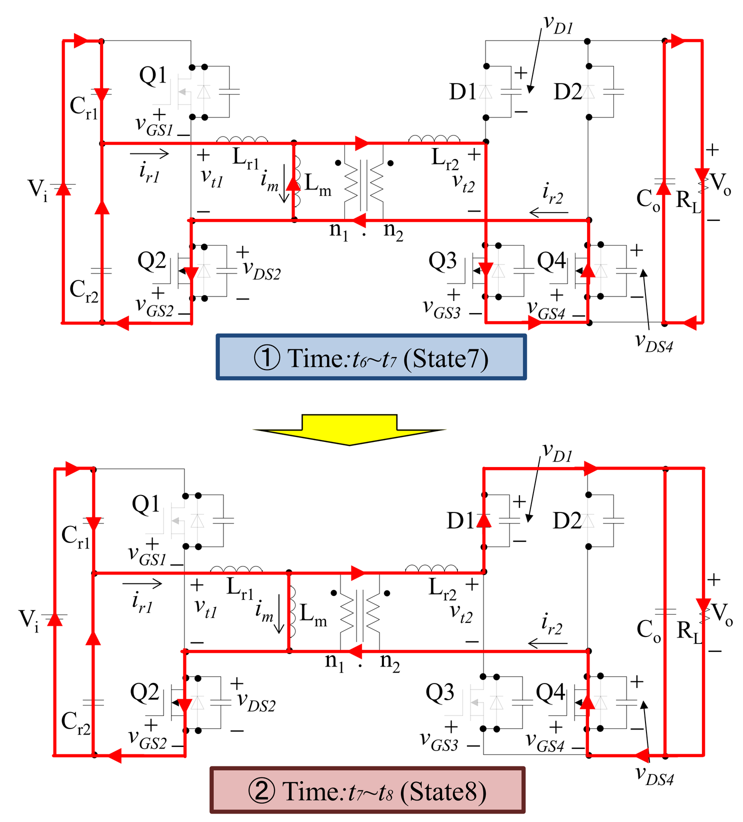
$$D = \frac{T_{on}}{T_s}$$

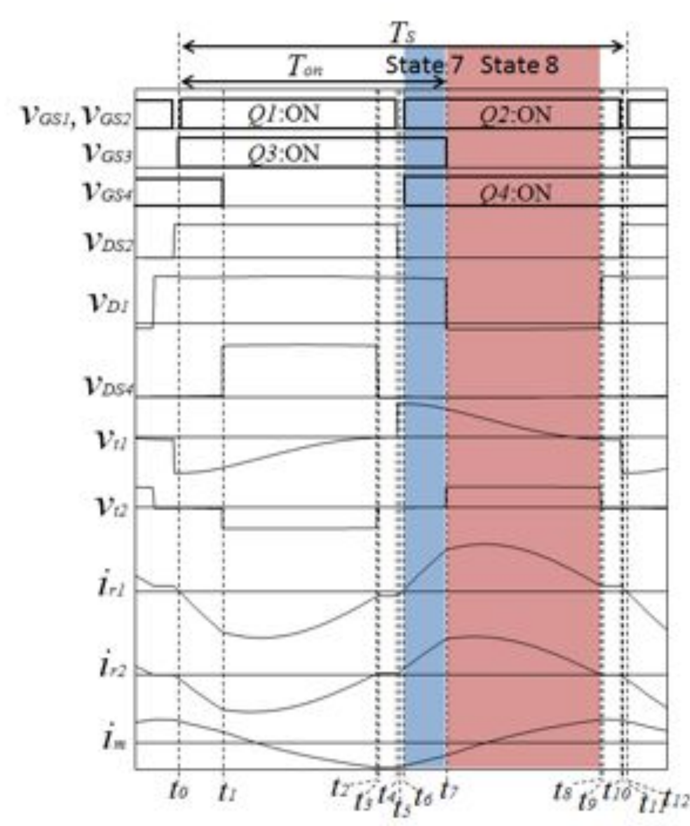


T_{on} : ON Time of Q3, Q4

T_s : Switching Time

Principle





PWM boost converter operation is composed of transformer's leakage inductance, synchronous rectifying switch, and diode on the output side.

① Inductance charging state

② Inductance discharging state

Experimental Results

Table.

Experimental Parameters

Output Voltage: V_o	12V
Transformer winding turns ratio: n_1: n_2	8 : 6
Leakage Inductance: L_r	100nH
Primary Leakage Inductance: L_{r1}	50nH
Secondary Leakage Inductance: L_{r2}	28nH
Magnetizing Inductance: L_m	1.2μF
Resonant Capacitor: C_{r1}, C_{r2}	150nF
Resonant Frequency: f_r	920kHz
Switching Frequency: f_s	1MHz

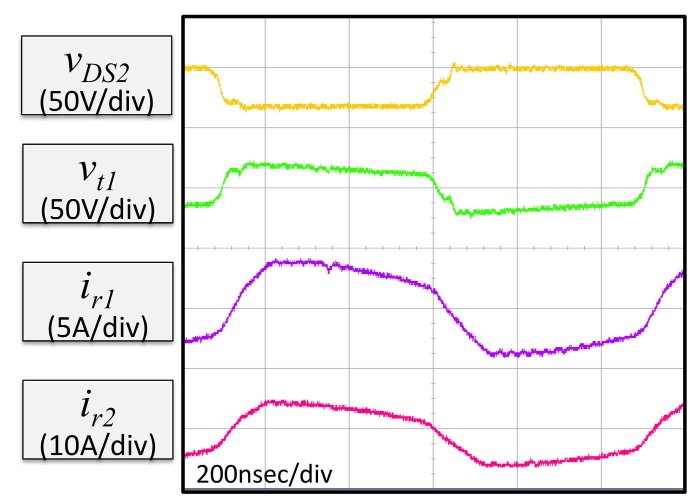
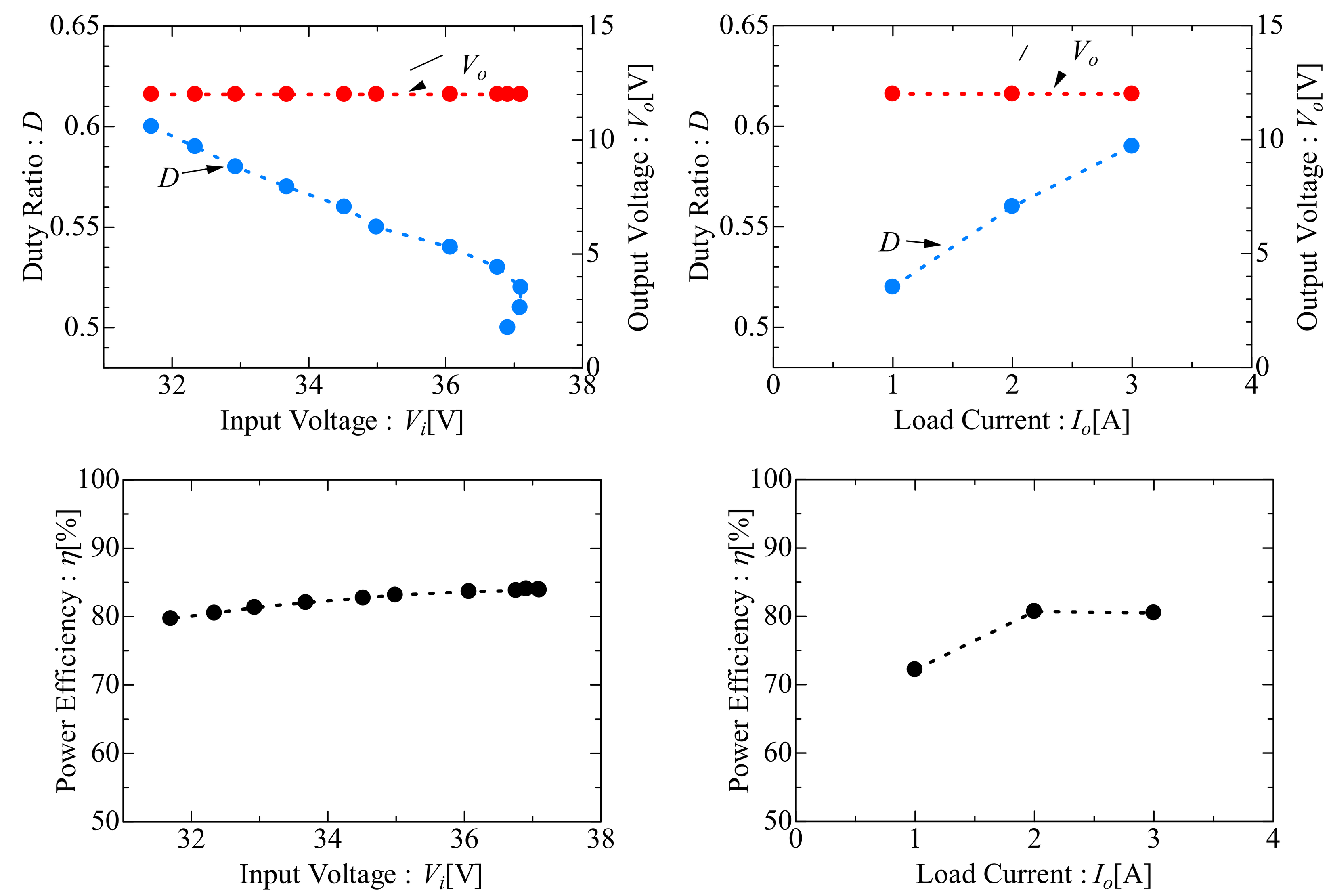


Figure.

Experimental Waveform



$I_o = 3A$, $V_o = 12V(const)$ $V_i = 32V$, $V_o = 12V(const)$

Figure. Measured characteristics of regulation

Future Work

- 5MHz switching frequency with digital PWM control
- Efficiency improvement
- Expanding input voltage and output current range
- Developing micro transformer
- Aim to implement "One-chip converter"