Low-Ripple-Voltage and High-Speed-Response Control System with MEMS Technology for Load Regulation of Switching Regulators

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I. Introduction

Demand of power supply circuits ➡ Low ripple (in steady state) and fast response for large load changes

Low ripple and fast response are trade-off in control systems.

e.g., large *L*: low ripple, small *L*: fast response

We proposed to use *variable inductors and capacitors*

II. Proposed DC-DC Converter using Variable Inductor and Capacitor

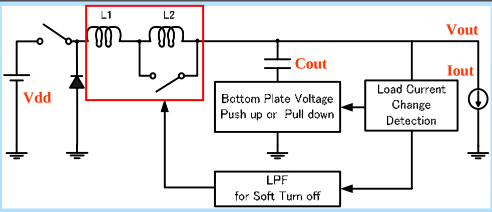


Fig.1 Proposed DC-DC converter with variable inductor, variable capacitor , load current change detection circuit and LPF.

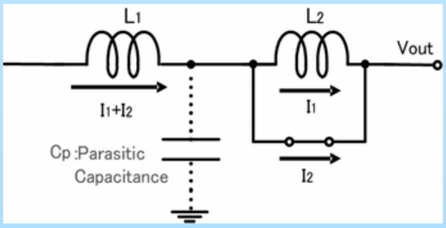


Fig.4 A series-inductor and a switch in ON-stage in Fig.1.

(1)When the load current is constant
-Turn OFF the switch and inductor value is L1+L2
➞Small output ripple

(2)When the load current increases (decreases) suddenly
-Turn ON the switch and inductor value is L1
-Increases (decreases) capacitor value
➞Fast response

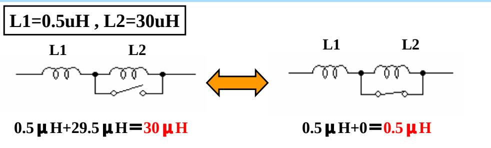


Fig.2 Variable inductor principle.

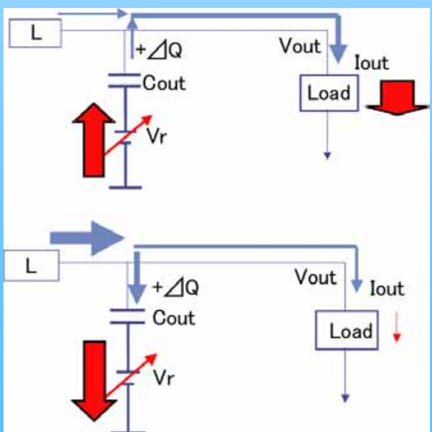


Fig.3 Variable capacitor principle.

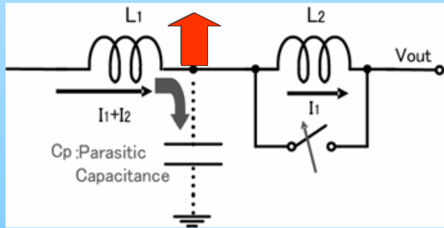


Fig.5 In case that the switch turns OFF suddenly, the current I2 flows into the parasitic capacitance which makes its node voltage high.

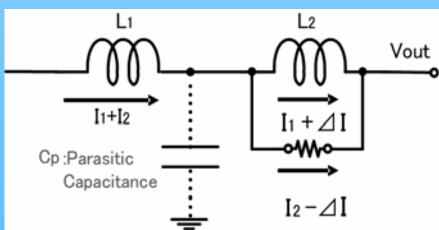


Fig.6 When the switch turns OFF softly, the circuit settles quickly.

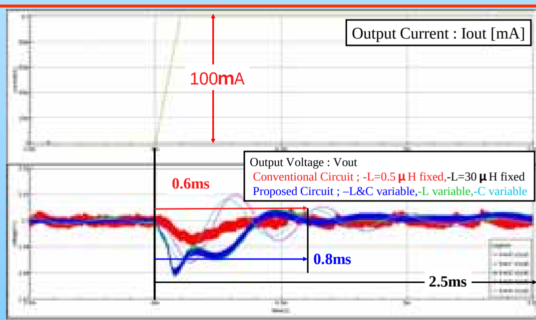
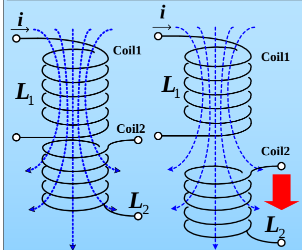


Fig.7 SPICE simulation result of the proposed DC-DC converter (Fig.1).

Table1. SPICE simulation result comparison.

	Response time	Ripple voltage
L=0.5uH fixed	0.6[ms]	7.0[mV]
L=30uH fixed	2.5[ms]	1.8[mV]
Variable C	0.6[ms]	2.5[mV]
Variable L	0.9[ms]	0.5[mV]
Proposed circuit variable L&C	0.8[ms]	2.0[mV]

III. Variable Inductor and Capacitor with MEMS Technology

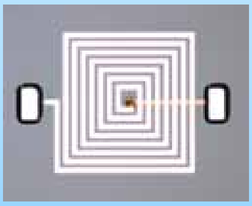


coil1, coil2 mutual inductance

$$M = k\sqrt{L_1 L_2}\ \ (k\text{:coupling factor})$$

Change distance between coils by actuator
⇩
Mutual inductance changes

Fig.8 Proposed variable inductor with MEMS actuator.



Specification
・16 turns
・Line width：16 [μm]
・Line space：45 [μm]
・Width：1.9 [mm]
・Material：AlSi
・Substrate：SiO2
・Quality factor (Q) ：4

Fabricated by
Fuji Electric Systems Co.Ltd.

Fig.11 Chip photo of spiral inductor.

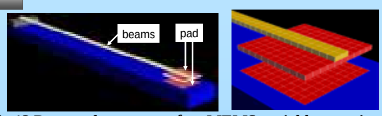


Fig.12 Proposed structure of an MEMS variable capacitor.

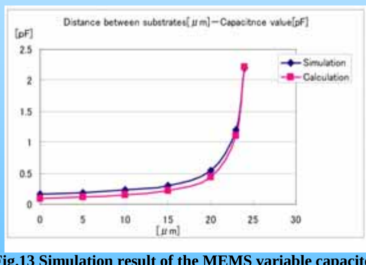


Fig.13 Simulation result of the MEMS variable capacitor.

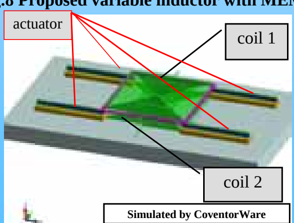


Fig.9 Proposed structure of variable inductor.

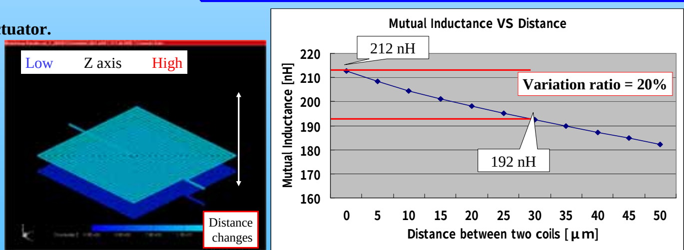


Fig.10 Simulation result of variable inductor (vertical move).

First proposal of variable inductors and capacitors usage in power supply systems.
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Feasible in future on-chip power supply systems.