20 juni 2017
1931 Congrescentrum Den Bosch
POWER ELECTRONICS 2017

Switched Capacitor Converter with continuous conversion ratio

Mert Turhan

20.06.2017

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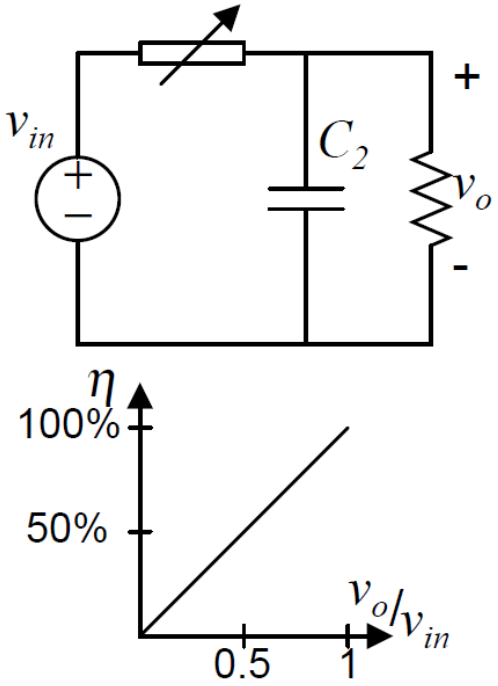
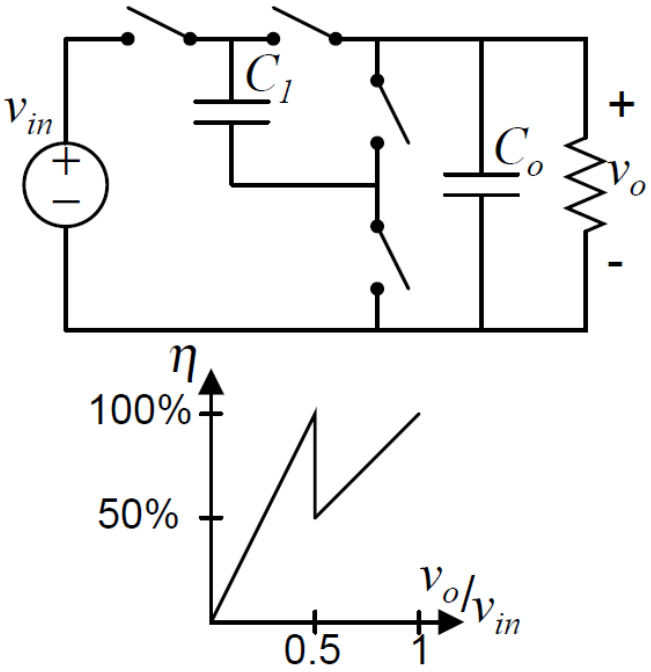
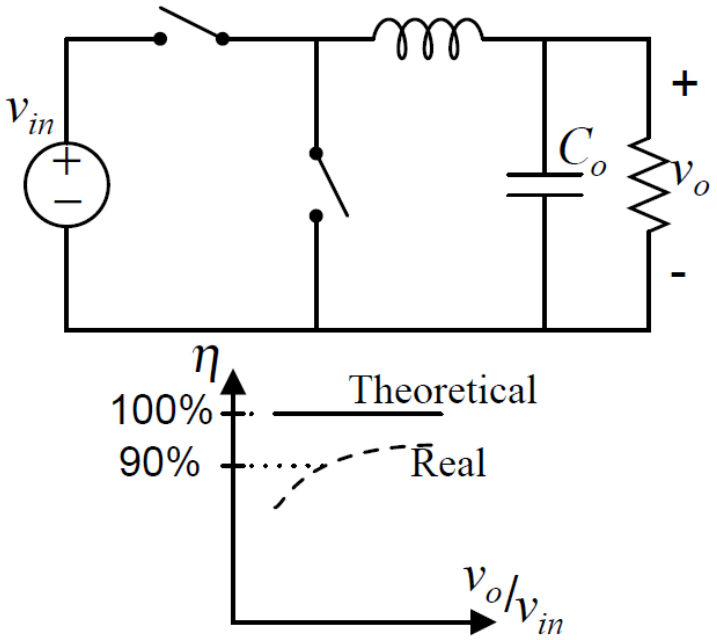
Where innovation starts

DC/DC converter topologies

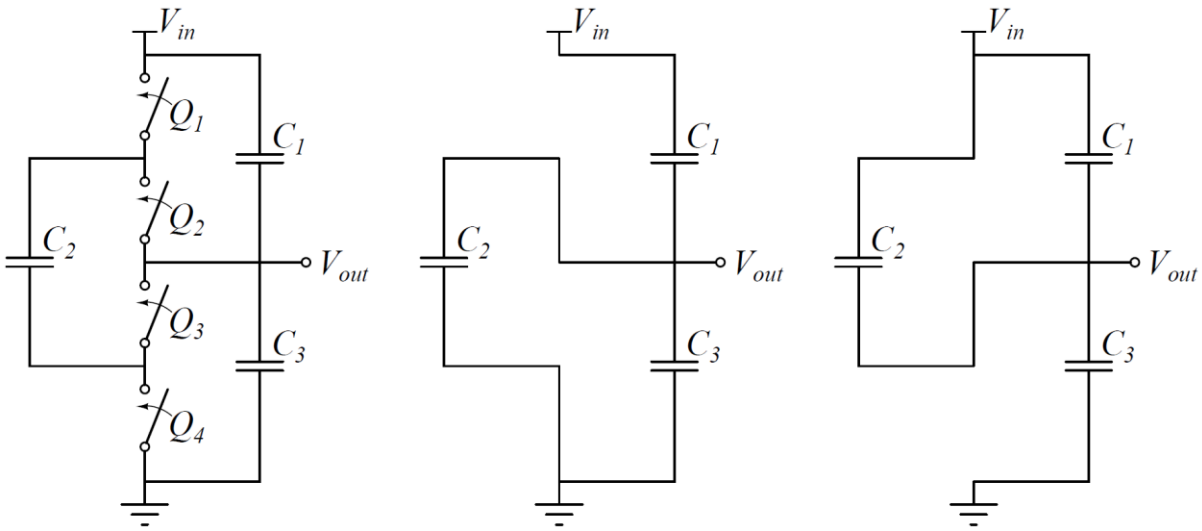
- Linear Regulator
- Capacitive Converter
- Inductive Converter

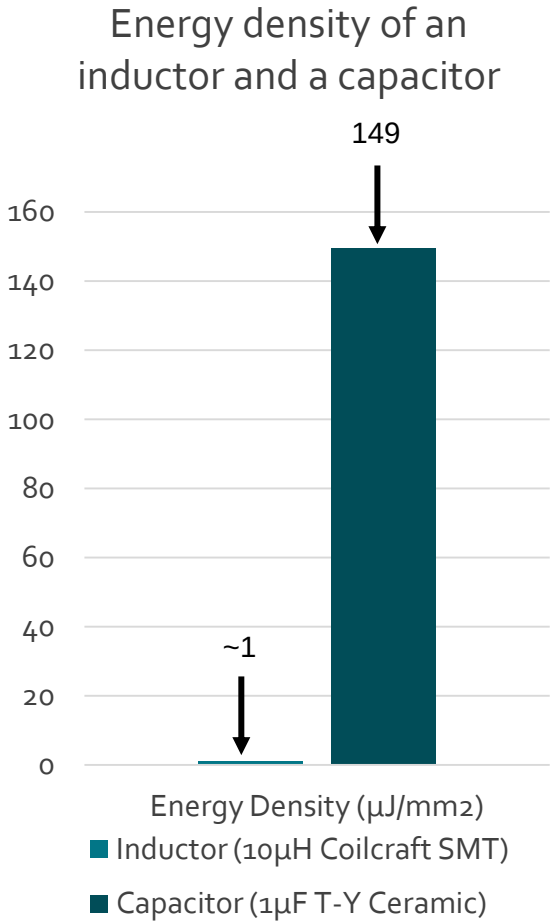






Advantages of Switched Capacitor Converter (SCC)





- No magnetic elements
  - No inductive switching losses
  - Can be fabricated as IC
- High power density

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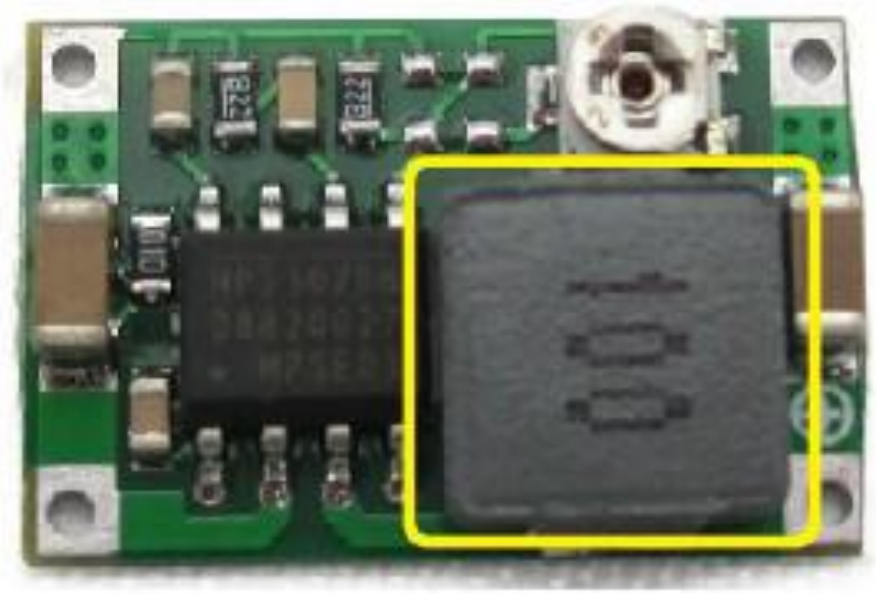
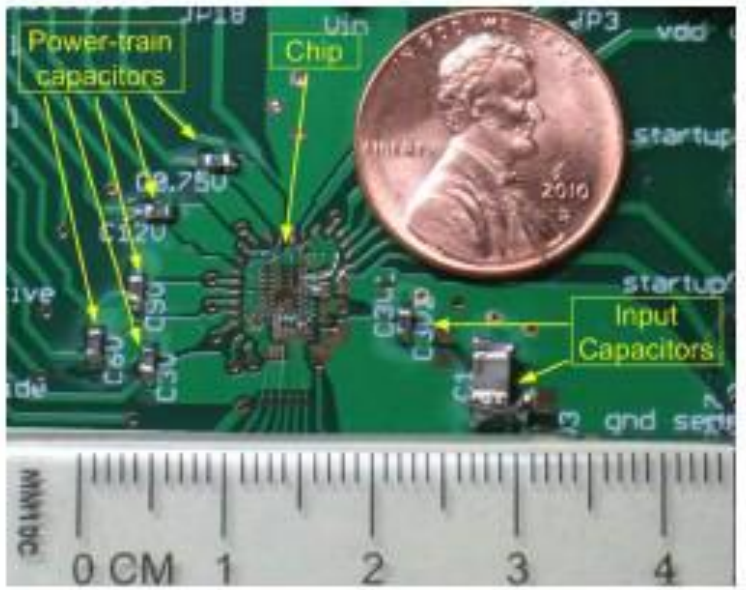
Integration

► Inductive



DC-DC step-down inductor based with the inductor marked. Vin=5V-23V, Vout=1V-17V and Iout=3A

► Capacitive



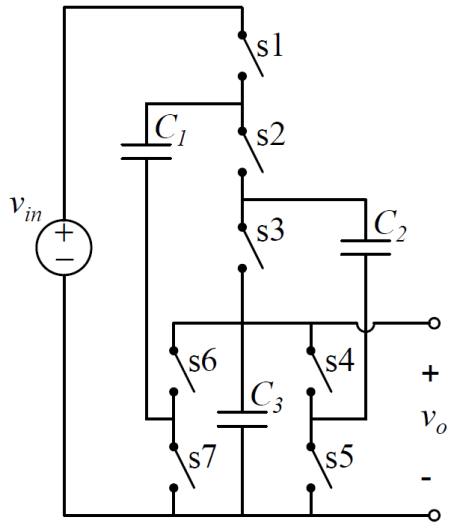
DC-DC step-down switched-capacitor converter (SCC) Vin=7.5V-13V, Vout=1V and Iout=1A

Source: V. Wai Shan Ng ,'Switched Capacitor DC-DC Converter: Superior where the Buck Converter has Dominated', PhD Berkely

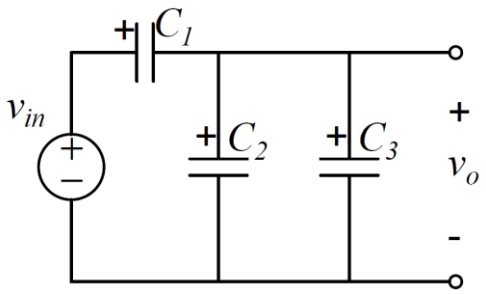
Why not SCC?

- Output voltage regulation is tied to efficiency
- Not suited for high current/power
- Lots of switches and gate driver
- Voltage balancing for many caps
- Current stress

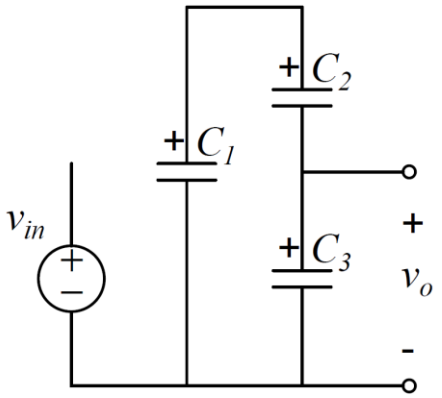
Voltage Conversion for Dickson Converter



3:1 Dickson Converter



First phase, odd switches are open



Second phase, even switches are open

$$V_o = V_{C3} = V_{C2} = \frac{V_{in}}{3}$$

$$V_{C1} = \frac{2V_{in}}{3}$$

$$m_i = \frac{V_o}{V_{in}} = \frac{1}{3}$$

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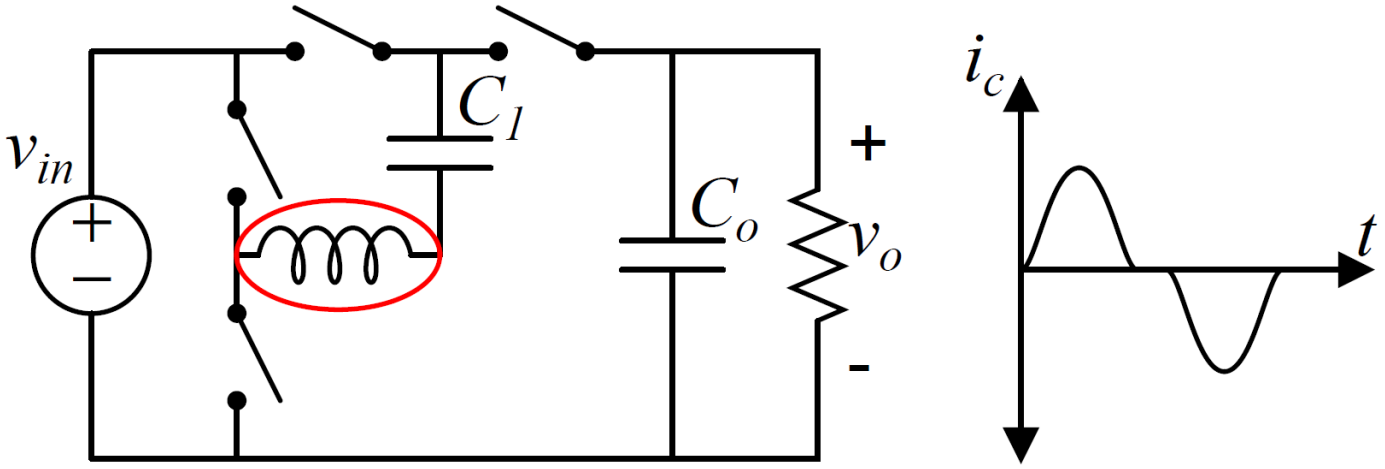
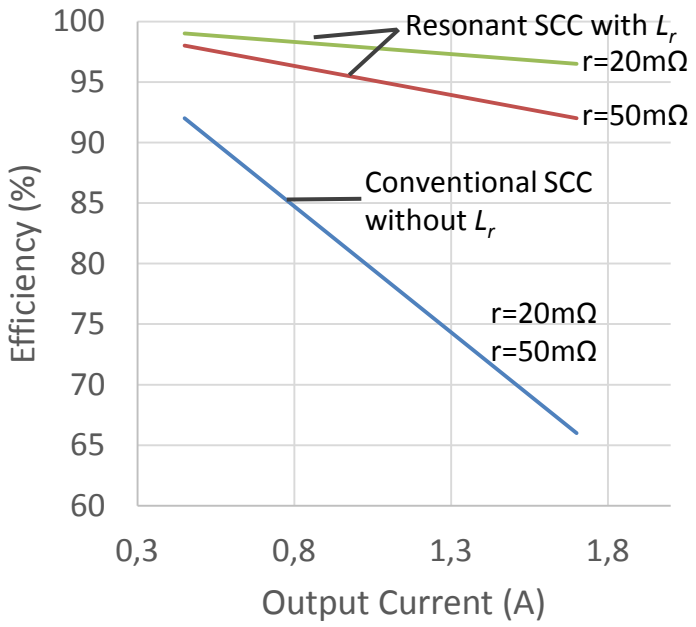
Step-up Switched Capacitor Converter

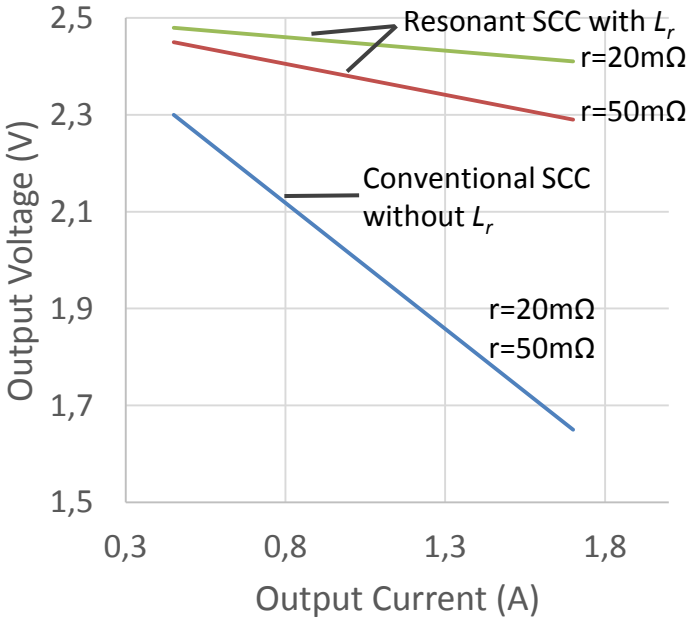
Resonant Switched Capacitor Converter



Resonant Switched Capacitor Converter

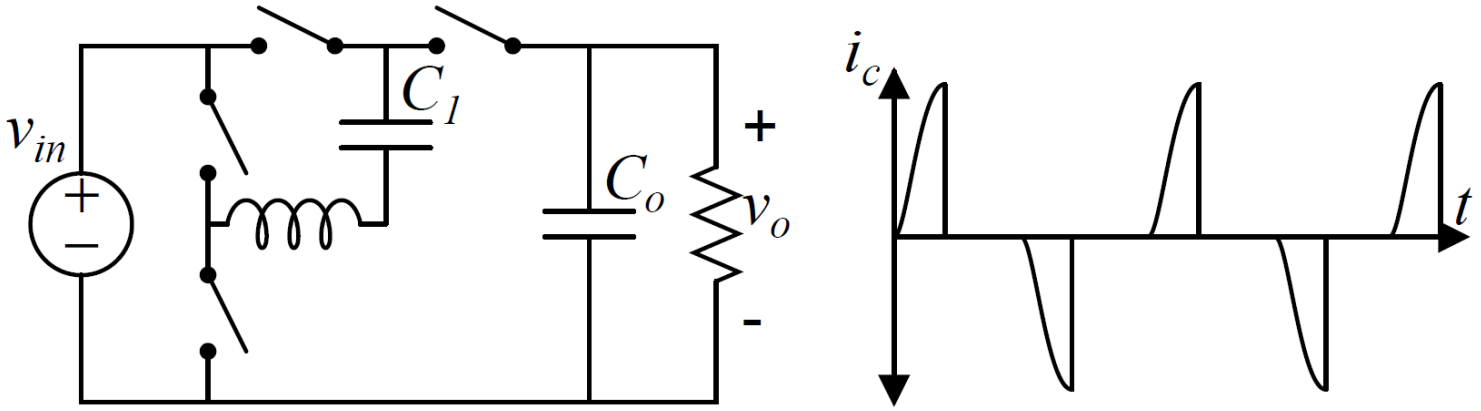
- Even the efficiency increases, the output voltage is discrete and is tied to the load



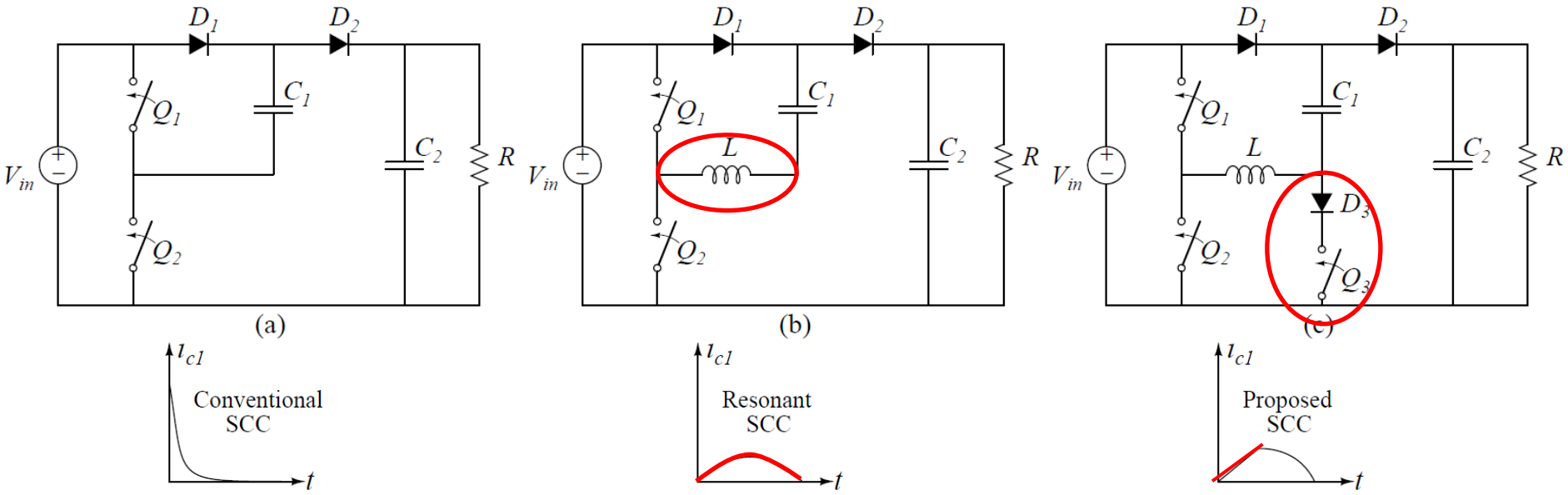


SCC with Continuous Conversion Ratio

Resonant Switched Capacitor Converter

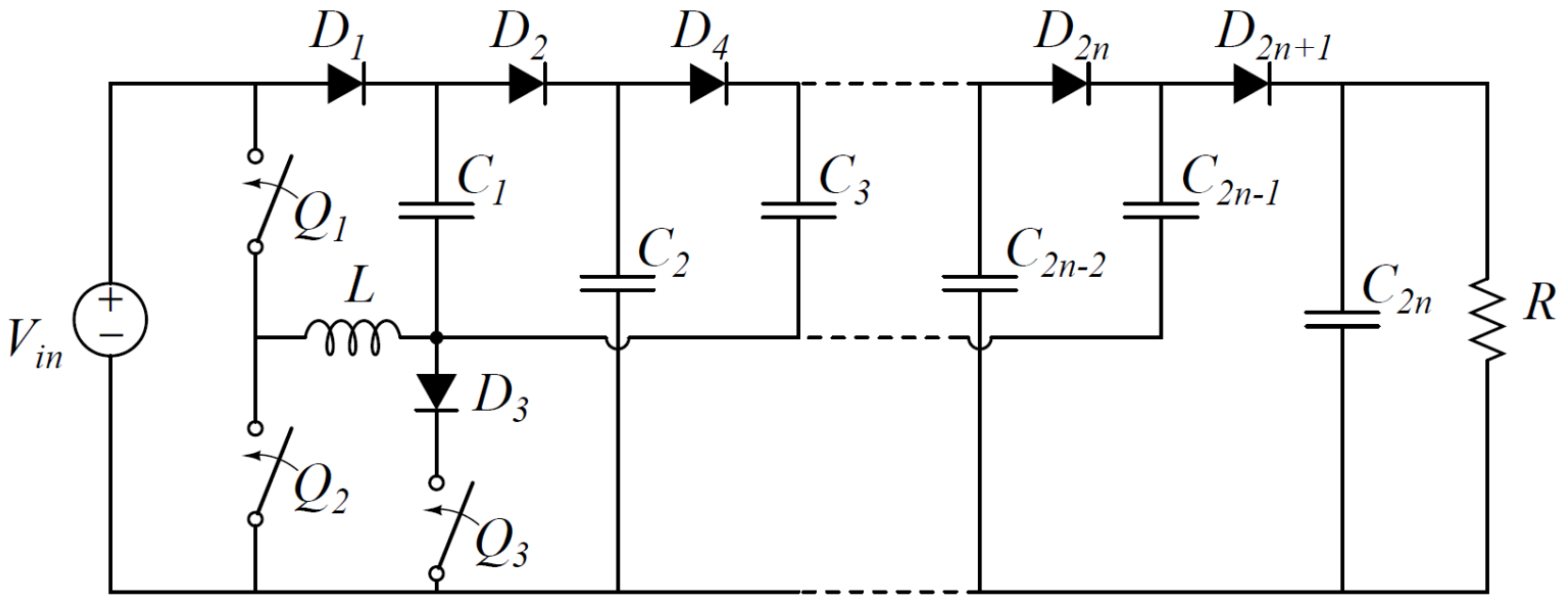


Derivation of SCC with Continuous Conversion Ratio

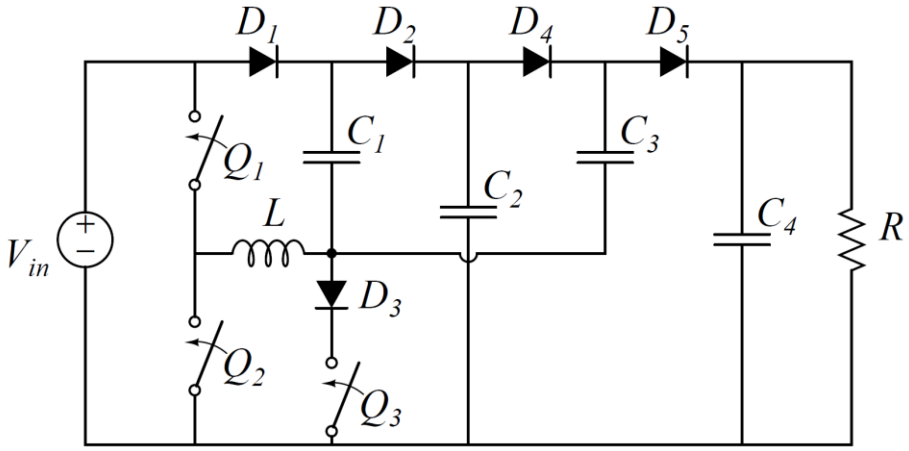


The step-up SCC

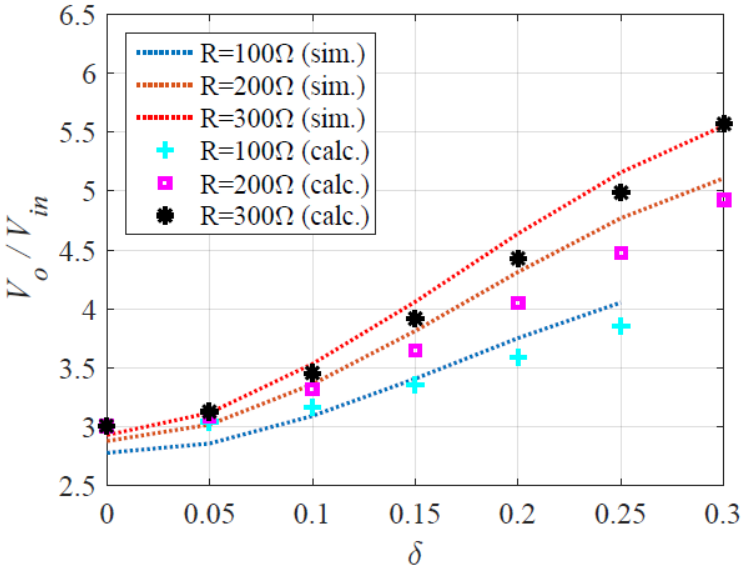
- To connect the capacitor cells in order to increase the conversion ratio



Step-up SCC with 2 SCs



Conversion Ratio versus duty cycle (δ)



$$\frac{V_o}{V_{in}} = \frac{(n+1)}{2}\left(1+\sqrt{1+\frac{2}{(n+1)^2}\frac{\delta^2 T_s}{\left(\frac{L}{R}\right)}}\right) \quad \boxed{n \Rightarrow 2} \quad \frac{V_o}{V_{in}} = \frac{3}{2}\left(1+\sqrt{1+\frac{2}{9}\frac{\delta^2 T_s}{\left(\frac{L}{R}\right)}}\right)$$

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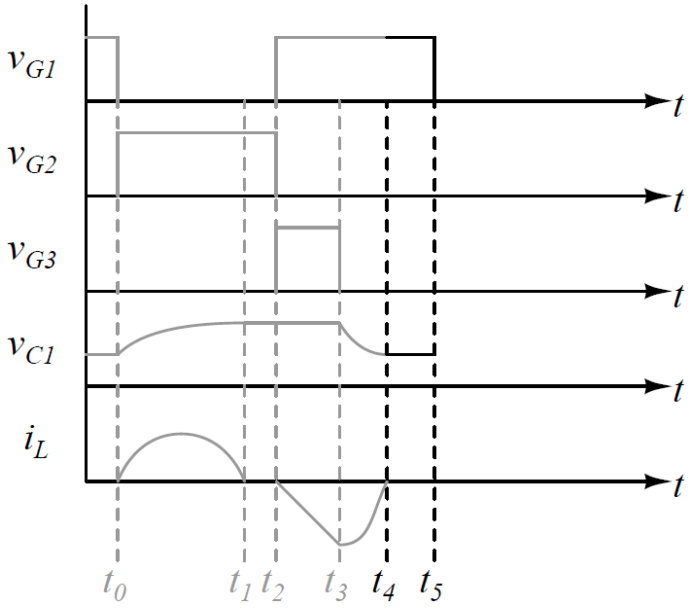
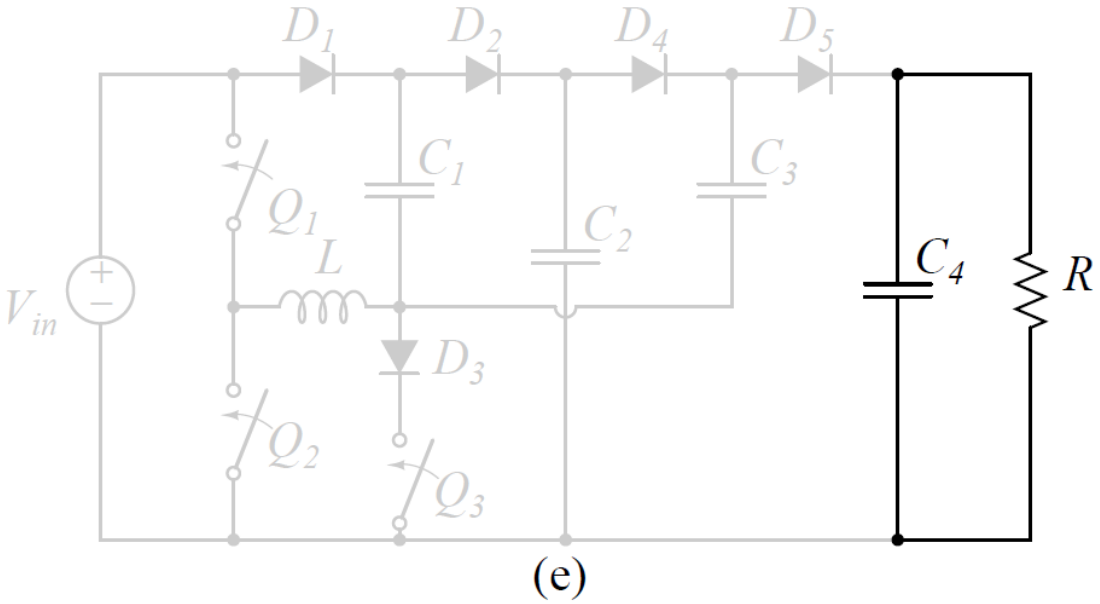
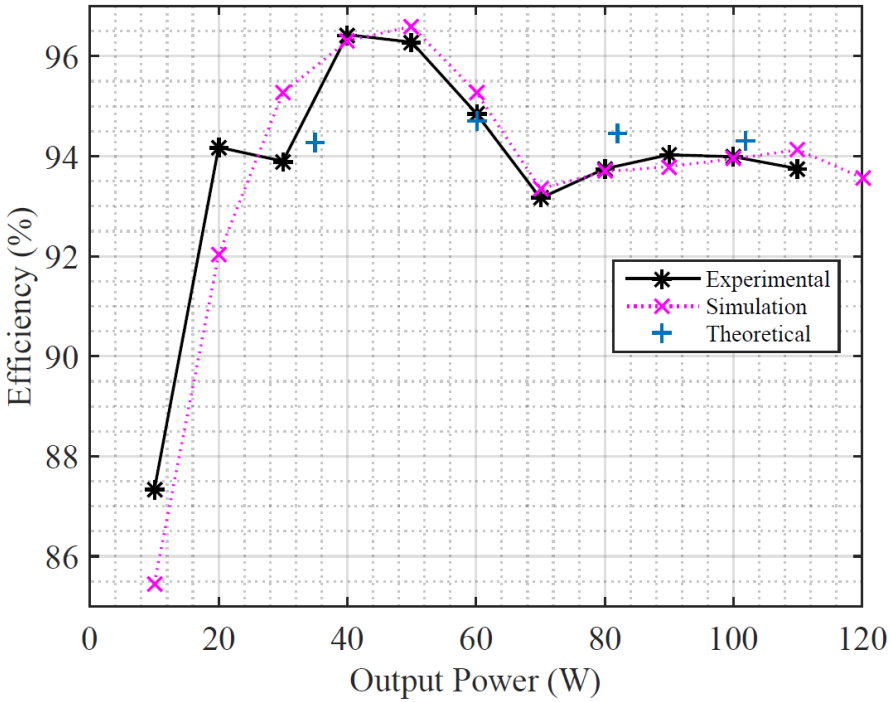
Operation of the step-up SCC



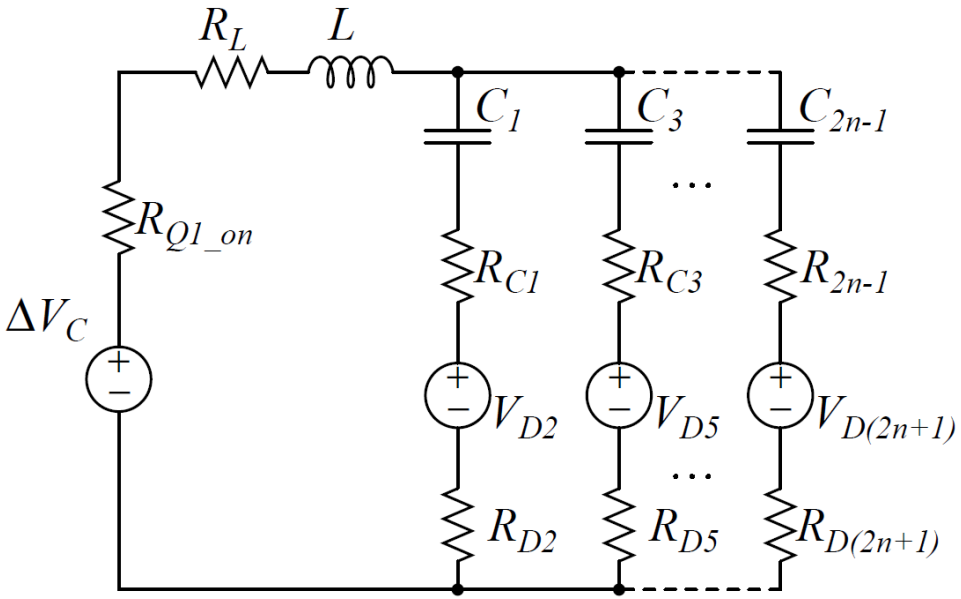


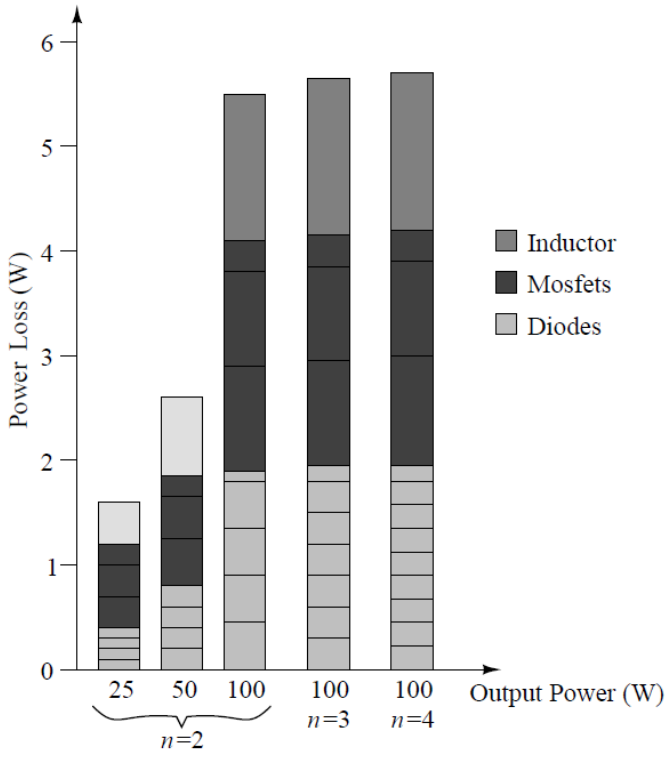
Efficiency

Parameters	
C_1, C_3	0.1µF
C_2, C_4	10µF
L	2.2µH
f_{sw}	215kHz
V_{in}	20-40V
P_{out}	100W



Loss distribution of the converter

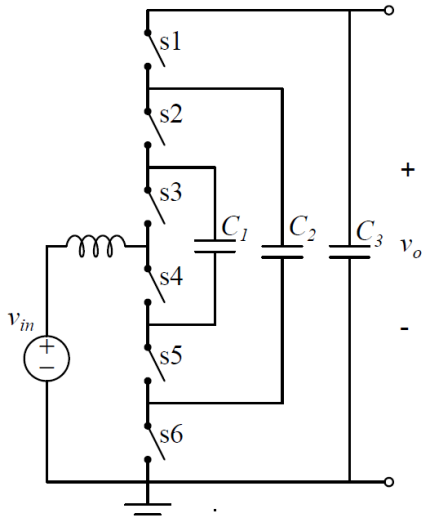


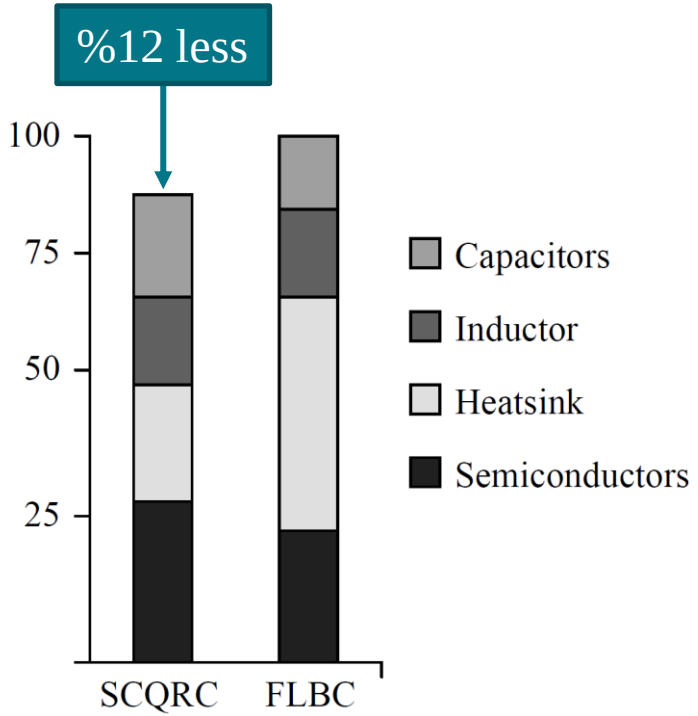


Size comparision

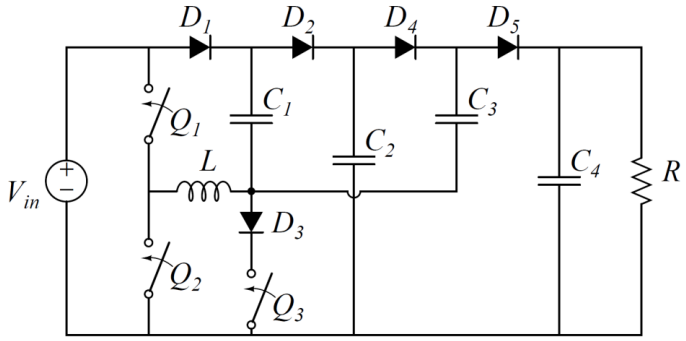
- Four Level Boost Converter (FLBC)

  Balancing circuit was not taken into account





- SCQRC



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Conclusions

- Capacitors may be used in order to minimize the size of the inductor
- There is no unbalancing problem at charge pump topoplogy
- Capacitor cells may be used to increase conversion ratio without extra loss

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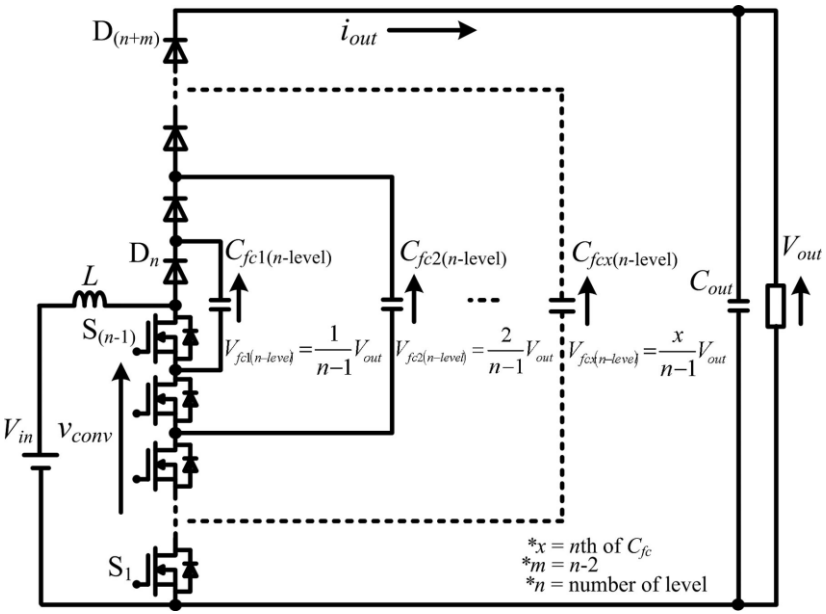
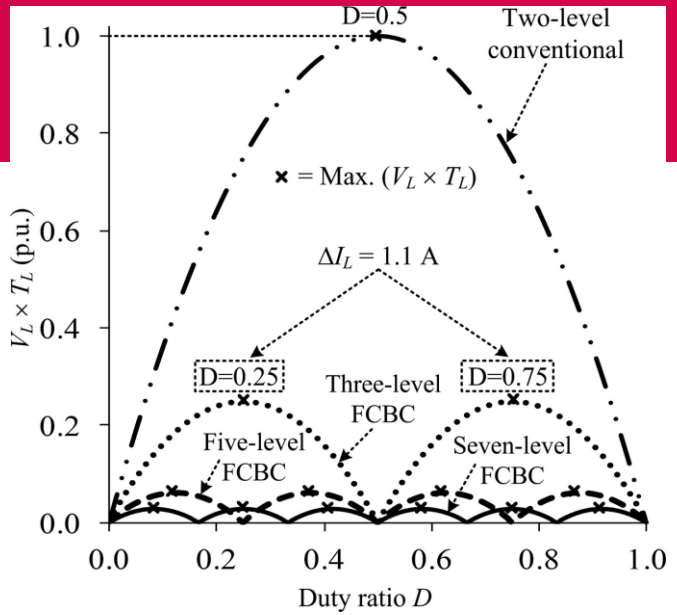
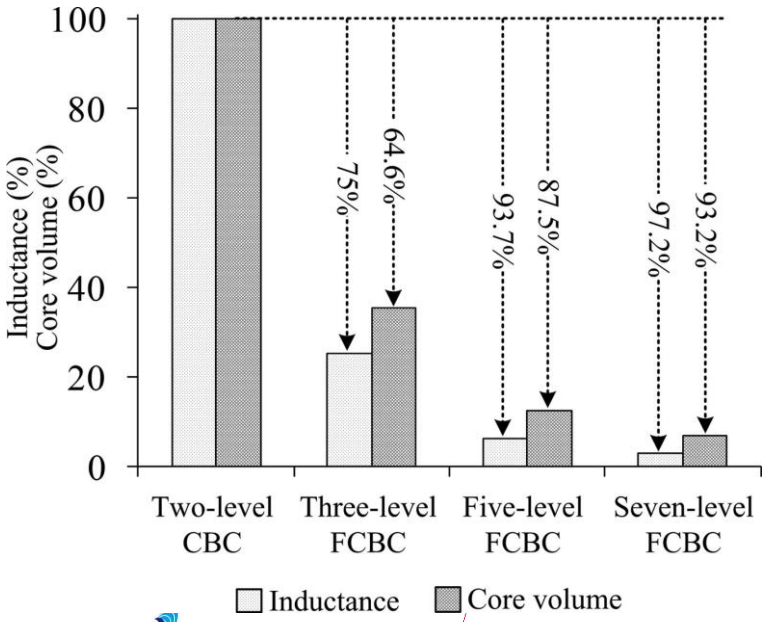
Where innovation starts







Source: Asmarashid Bin Ponniran, Koji Orikawa, and Junichi Itoh, Minimum Flying Capacitor for *N*-Level Capacitor DC/DC Boost Converter

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