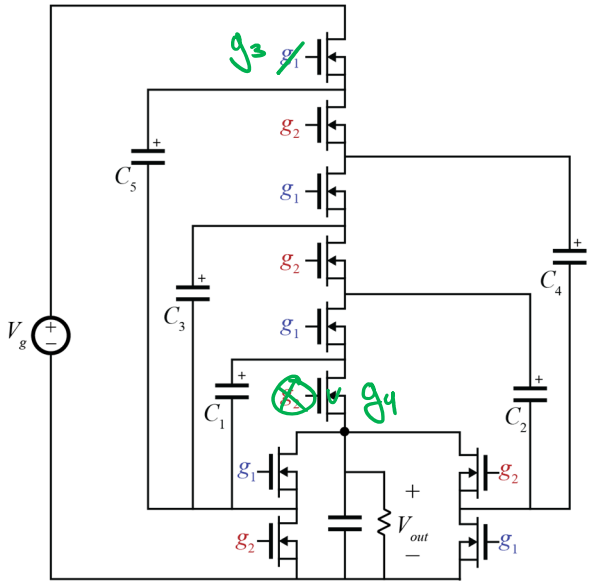
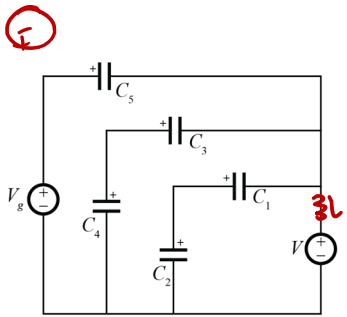
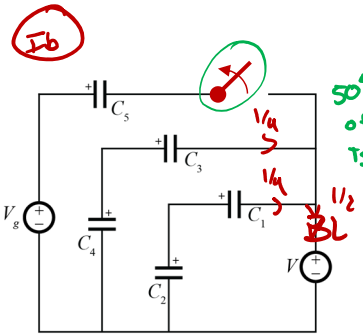
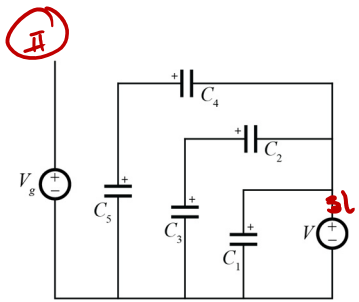
Split-Phase Control

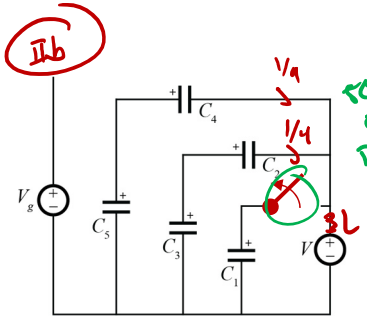


Split-Phase Control









$\bar{a}_c$ — Duty cycles

50% of T_S

$\bar{a}^{I} = [\ -\frac{1}{4} \quad \frac{1}{8} \quad -\frac{1}{8} \quad \frac{1}{8} \quad -\frac{1}{8} \quad \frac{1}{4} \quad \frac{1}{2}\ ]$ /gout — D_I

$\bar{a}^{Ib} = [\ \phi \quad \frac{1}{4} \quad -\frac{1}{4} \quad \frac{1}{4} \quad -\frac{1}{4} \quad \phi \quad \frac{1}{2}\ ]$ /gout — D_{Ib}

$C_1 \quad C_2 \quad C_3 \quad C_4 \quad C_5$

50% of T_S

$\bar{a}^{II} = [\ \phi \quad -\frac{1}{4} \quad \frac{1}{8} \quad -\frac{1}{8} \quad \frac{1}{8} \quad -\frac{1}{8} \quad \frac{1}{2}\ ]$ /gout — D_{II}

$\bar{a}^{IIb} = [\ \phi \quad \phi \quad \frac{1}{4} \quad -\frac{1}{4} \quad \frac{1}{4} \quad -\frac{1}{4} \quad \frac{1}{2}\ ]$ /gout — D_{IIb}

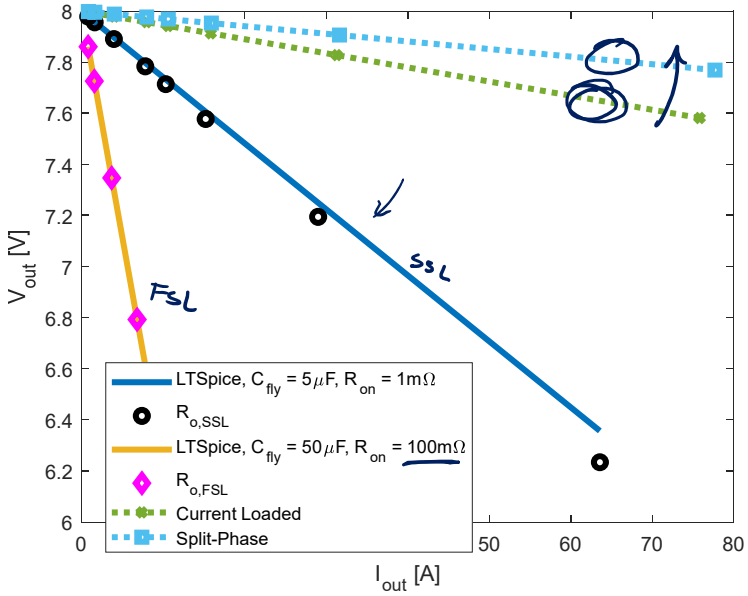
$D_I + D_{Ib} = 50\%$ $\qquad$ $D_{II} + D_{IIb} = 50\%$

$$[D_I \ D_{Ib} \ D_{II} \ D_{IIb}] \begin{bmatrix} \bar{a}^{I} \\ \bar{a}^{Ib} \\ \bar{a}^{II} \\ \bar{a}^{IIb} \end{bmatrix} = \begin{bmatrix} -\frac{1}{6} & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

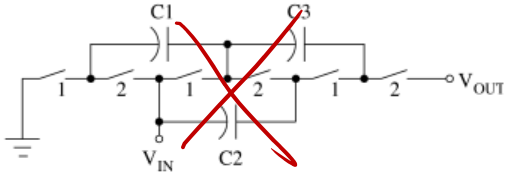
$D_I = D_{II} = 2/6$

$D_{Ib} = D_{IIb} = 1/6$

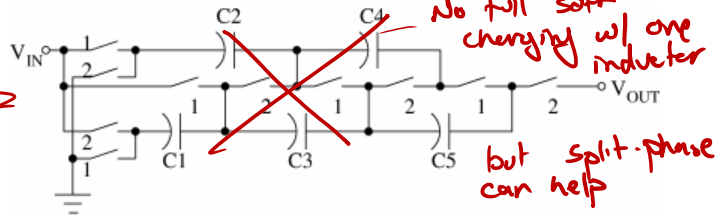
LTSpice Simulation



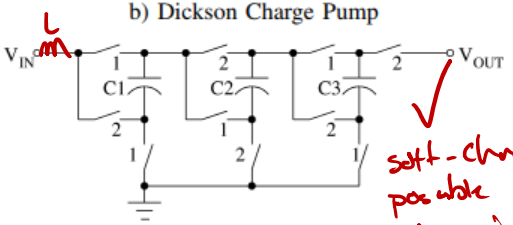
Complete Soft Charging



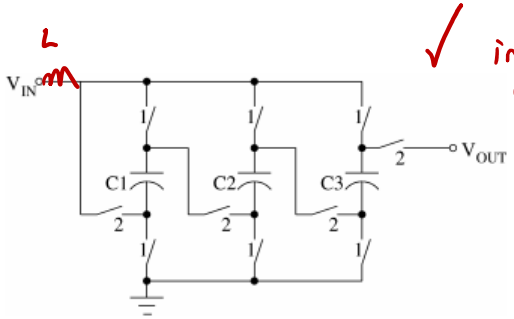
a) Ladder



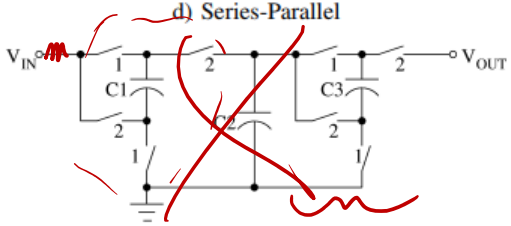
b) Dickson Charge Pump



c) Fibonacci



d) Series-Parallel



e) Doubler

Y. Lei and R. Pilawa, "A General Method for Analyzing Resonant and Soft-Charging Operation of Switched-Capacitor Converters" TPEL 2014

S. R. Pasternak, M. H. Kiani, J. S. Rentmeister and J. T. Stauth, "Modeling and Performance Limits of Switched-Capacitor DC–DC Converters Capable of Resonant Operation With a Single Inductor", JESTPE 2017

FCML and SC Buck