Single Phase Buck

Q_1 ON
L_1 stores ℓ

Q_1 off
Q_2 ON
L_1 sources load

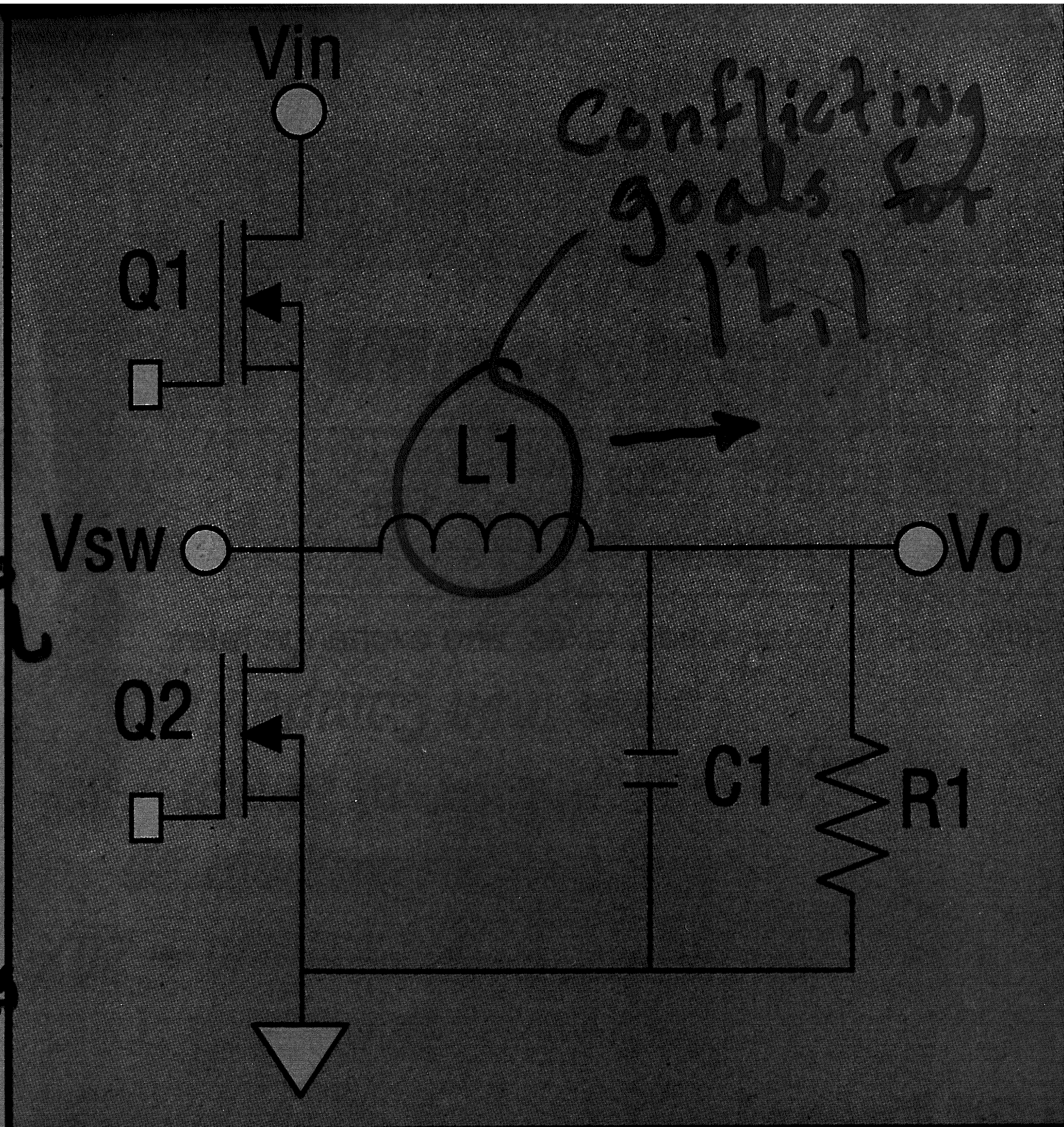

Fig. 1. *Simplified schematic of a typical synchronous buck converter. The inductor current always flows through either Q1 or Q2. During the on-time, Q1 is ON, and inductor current increases. During the off-time, Q2 is ON, and the inductor current decreases. At the on/off transition times, the inductor current has to quickly switch from one FET to the other one.*

High L for low ripple
Low L for fast $di(out)/dt$

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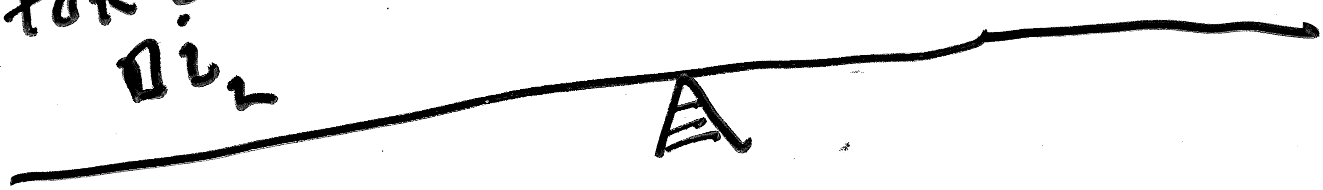
I_{out}: 50A notebook, 100A desktop, 150A server } I^2R losses high for one path

Conflict / Compromise on <u>single</u> "L" is necessary

Big "L" for small Δi_L

small "L" for fast $\frac{di_L}{dt}$



Solution: "x" seperate current paths each with own

S_x and L_x

Shift phases to reduce $|\Delta i_L|$

$$\sum_{x=1}^{N} i_x = i_{out}$$

Phase shift Δi_x to minimize $\Delta i(out)$

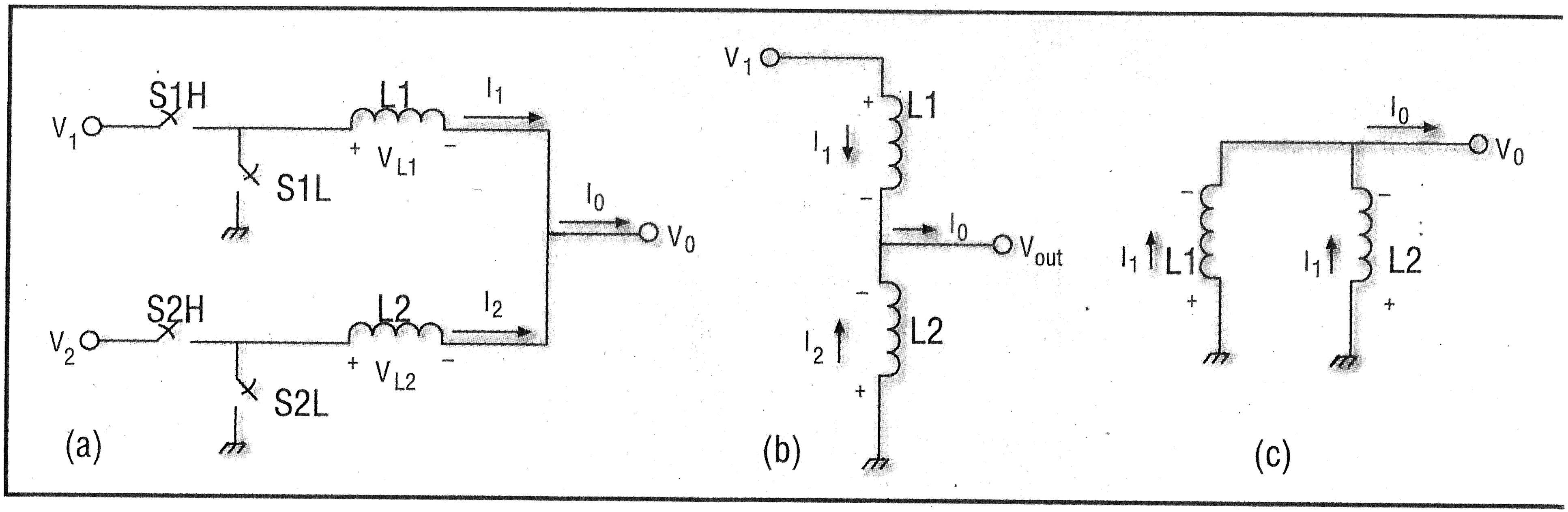


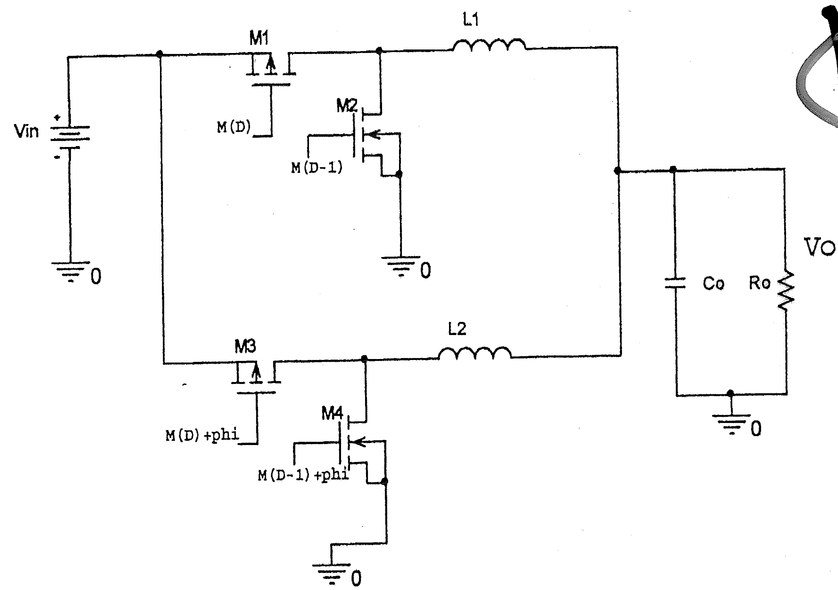
Fig. 2. *A simplified schematic of a multiphase uncoupled buck regulator (a) illustrates the two basic switching actions. In state one (b), S1H and S2L are closed while S1L and S2H are open. The input then sources energy to L1 and the output, and L2 sources energy to the output. In state two (c), S1L and S2L are closed, and S1H and S2H are open. Thus, both inductors source energy to the output. These operations are reversed for states three and four (not shown).*

I^2R loss @ 150 A server too high for one path use several parallel paths

Multiphase Output: $|I_M| \downarrow$ yet $|I_o|$ same

$|\Delta i_L| \downarrow$

$|I_{IN}| \downarrow$



Loss due to I_{IN} ⇓ as N

$I_{IN}^2 R_{Lm}$ loss down as N^2

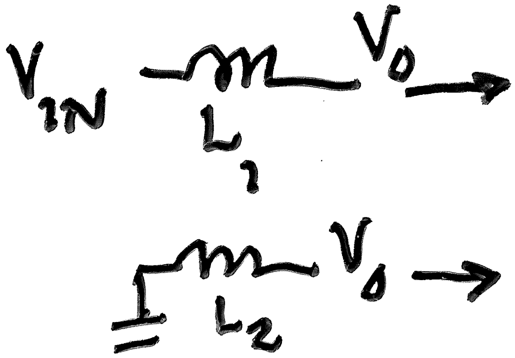
-Reduces output ripple due to cancellation of inductor ripple currents

-Relaxes maximum current rating requirements of switches, inductors and caps

-Reduces stress and I^2R loss on input source by reducing amplitude of input current pulses

① State 1: 2Φ $0 \to DT_{SW}$

$dt = DT_{SW}$



$L_1 = L_2 = L$

$$di_1 = \frac{V_1}{L_1}(1-D)\,DT_{SW}$$

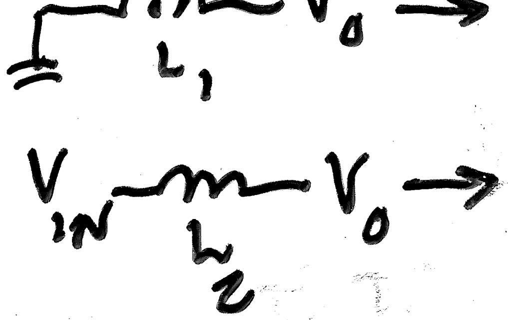
$$di_2 = \frac{V_{IN}}{L_2}(D)\,DT_{SW}$$

$L_1 = L_2 \qquad di_{out} = di_1 + di_2$

$$di_{out} = \frac{V_{IN}}{L}(1-2D)\,DT_{SW}$$

② State 2: 2Φ

$t = DT_{SW} \to \frac{T_{SW}}{2}$



ripple is at $2 f_{SW}$

$$di_{out} = -\frac{V_{IN}}{L}(1-2D)\,DT_{SW}$$

! Recall $\Delta i(out)$ 1Φ: $\frac{V_{IN}}{L}(1-D)\,D\,T_{SW}$!

$$\frac{\Delta i_{out}(2\Phi)}{\Delta i_{out}(1\Phi)} = \frac{1-2D}{1-D}$$

lower Δi_{out} for all D

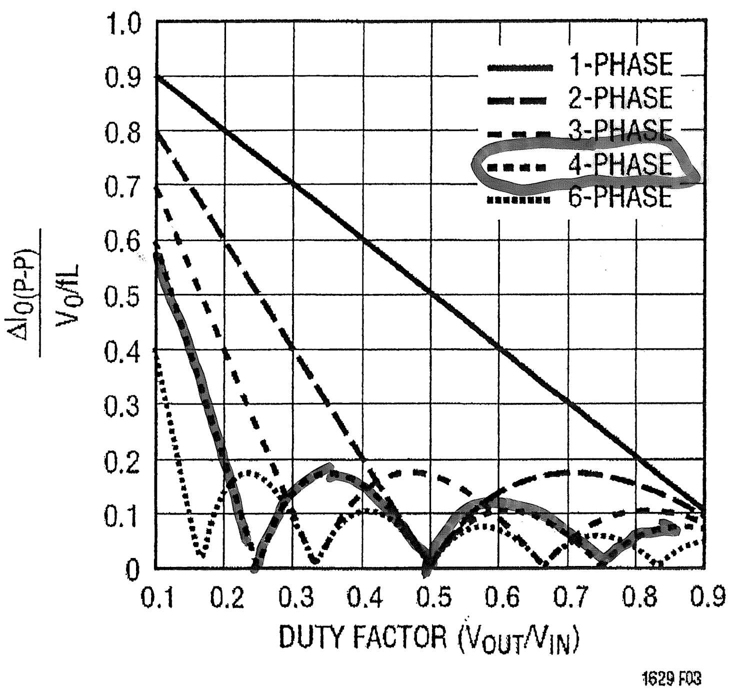
OR

L reduced for same Δi_{out} but faster di_L/dt

Δi_{out} (multiphase) can be zero for some D

Frequency and Phases

For Vin = 5V, Vout = 1.8V, D≈.35



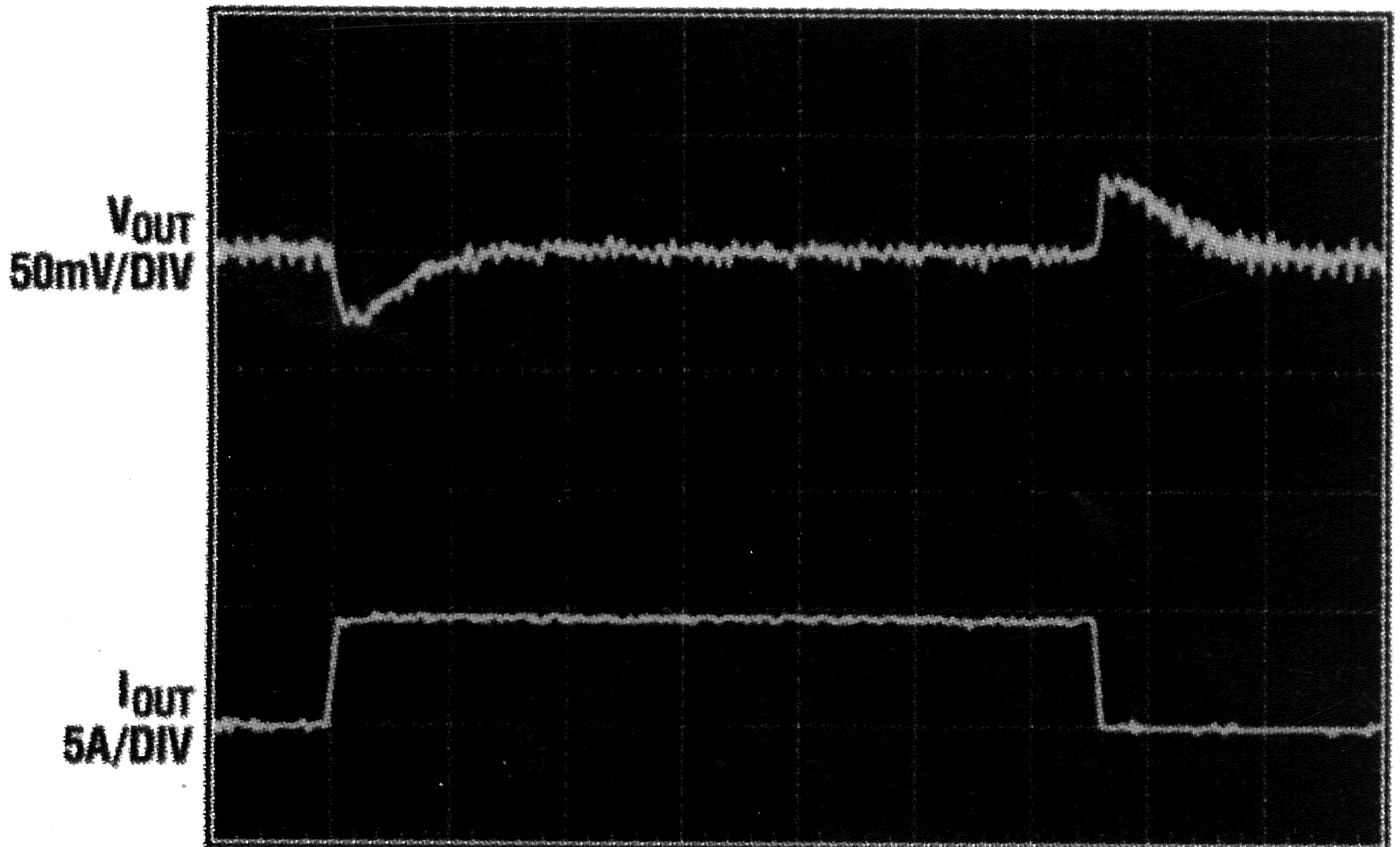
- Optimal number of phases 3 or 6
- Though 4 or even 2 phases also provides good output ripple cancellation versus a single phase

$\Delta i_4(out) = 0$ @ D =

0.25
0.50
0.75

Ultrafast Transient Response

2% ΔV_{OUT} with a 5A Step



V_{IN} = 12V, V_{OUT} = 1.5V, 0A to 5A Load Step

(C_{OUT} = 3 x 22µF CERAMICS, 470µF POS CAP)