Switch Mode Power Supplies: SPICE Simulations and Practical Designs
Christophe Basso – August 2008

Corrections of typos, mistakes and errors found by readers (or by the author himself!)
Second print

Page 455: below Fig. 5-10a: …we have installed a divider by 11 such that the upper current limit (2.5 A) corresponds to a 1.1-V output voltage.
Contributed by Umut DEMIREZEN, 5/10/2008

Page 457: in bullet 4., the calculation refers to a 70-° phase margin and not a 60-° target.
Contributed by Umut DEMIREZEN, 5/10/2008

Page 501: Equation 6-41b is wrong but the result is ok:

\[ I_{d,\text{avg}} = \frac{P_{\text{conv}}}{2\eta V_{\text{bulk,avg}}} = 0.56 \, A \] (6-41b)

Page 765: Equation 8-24 has an extra letter for the \( C_{\text{lump}} \) term. It should read:

\[ P_{\text{sw,lump}} = \frac{1}{2} C_{\text{lump}} V_{\text{in}}^2 F_{\text{sw}} \] (8-24)

Contributed by Prapat Chumchairat, 30/8/2008

Page 767: the unequality sign is not on the right direction for Eq. (8-28). It should be:

\[ \frac{1}{2\pi\sqrt{L_{\text{mag}}C_T}} \gg \frac{1}{2T_{\text{sw}}(1 - D_{\text{max}})} \] (8-28)

Contributed by Prapat Chumchairat, 30/8/2008

Page 827: the equivalent inductor calculation for the forward was actually carried for non-coupled inductors. This correction has been reported to me by Mr Arturo Galgani who kindly shared his derived formulas.

In a transformer respectively featuring primary and secondary inductors \( L_1, L_2 \), respectively affected by turns \( N_{L1} \) and \( N_{L2} \), the input voltage \( V_1 \) and output voltage \( V_2 \) are linked by:

\[ V_1 = L_1 \frac{dI_{L1}}{dt} + M \frac{dI_{L2}}{dt} = L_1 S_1 + M \cdot S_2 \]

\[ V_2 = L_2 \frac{dI_{L2}}{dt} + M \frac{dI_{L1}}{dt} = L_2 S_2 + M \cdot S_1 \]

Where \( S \) is current slope in each inductor and \( M \) represents the mutual inductance defined by:
\[ M = k \sqrt{L_1 L_2} \quad \text{with } k \text{ the coupling coefficient} \]

Solving for the respective slopes:

\[ S_1 = -\frac{L_2 V_1 - MV_2}{M^2 - L_1 L_2} \quad \text{and} \quad S_2 = -\frac{L_1 V_2 - MV_1}{M^2 - L_1 L_2} \]

We know that \( N \) turns wound on a magnetic medium affected by a specific inductor factor \( A_i \) give an inductor \( L \) equal to: \( L = A_i N^2 \)

\[ L_1 = N_{L_1} A_i \quad \text{and} \quad L_2 = N_{L_2} A_i \]

\[ M = k \sqrt{L_1 L_2} = k N_{L_1} N_{L_2} A_i \]

For proper current balance in the coupled inductors, we have \( \frac{N_{L_2}}{N_{L_1}} N_i = \frac{N_{L_1}}{N_{L_2}} N_{L_2} \). Therefore,

\[ N_{L_2} = N_{L_1} N_i, \quad \text{where } N_1 \text{ and } N_2 \text{ are the turns ratios of the forward transformer respectively delivering } V_{o1} \text{ and } V_{o2}, \text{ where } N_{L1} \text{ and } N_{L2} \text{ are the turns ratios of the coupled inductors.} \]

Substituting the above in \( M \) gives us:

\[ M = k N_{L_1} \frac{N_{L_2}}{N_{L_1}} N_i A_i = k N_{L_1} \frac{N_{L_2}}{N_{L_1}} A_i \]

In CCM, both output voltages are linked by a coefficient \( \alpha \):

\[ N_2 = \alpha N_1 \quad \text{and} \quad V_{o2} = \alpha V_{o1} \]

The voltage across the inductors is defined by:

\[ V_2 = V_{in} N_2 - V_{o2} \quad \text{and} \quad V_1 = V_{in} N_1 - V_{o1} \]

\( M \) can be updated to become: \( M = k N_{L_1} \frac{\alpha N_1}{N_1} A_i = k N_{L_1} \frac{\alpha}{N_{L_1}} A_i \)

The output voltage \( V_{o2} \) and the second inductor \( L_2 \) can be re-defined in relationship to \( V_{o1} \) and \( L_1 \):

\[ V_2 = V_{o2} \alpha N_1 - \alpha V_{o1} = \alpha \left( N_1 V_{in} - V_{o1} \right) \]

\[ L_2 = \left( N_{L_1} \alpha \right)^2 A_i \]

Substituting the above in the first transformer definitions leads us to:
The primary reflected slope is simply the sum of the individual slopes:

\[ S_p = s_1 N_1 + S_2 N_2 \]

We know that \( N_2 = \alpha N_1 \), therefore:

\[ S_p = N_1 \left( S_1 + \alpha S_2 \right) \]

Finally, we have:

\[ S_p = -\frac{2N_1 \left(V_{o1} - N_1 V_{in} \right)}{A_j N_{L1}^3 \left(k + 1\right)} \]

by replacing \( A_j N_{L1}^2 \) by \( L_1 \) and divided by \( N_1 \), we have:

\[ S_p = \frac{V_{o1} - V_{o1}}{L_1 \left(k + 1\right)} \]

From which we can extract the equivalent inductor seen from the primary:

\[ L_{eq} = \frac{L_1 \left(k + 1\right)}{N_1^2} \]

For a converter featuring \( p \) outputs, the equivalent inductor is:

\[ L_{eq} = \frac{L_1 \left(p - 1\right)k + 1}{p} \]

For those interested by the small-signal model of the multi-output forward converter with coupled inductors, please read the following paper written by Milan Jovanonic:


Contributed by Arturo Galgani, 15/11/2008

**Page 834:** in the equation 8-124, this is \( I_p \) and not \( I_D \) that is used:

\[ P_{\text{cond}} = I_{p,\text{rms}}^2 R_{\text{DS(on)}} \enspace @ \enspace T_j = \ldots \]  

**Page 834:** in the equation 8-125c, the voltage across the MOSFETs in a 2-SW forward converter before turn-on is actually half the bulk voltage if the DS capacitances are balanced. Therefore the equation has to be updated with a further division by 2:

\[ P_{\text{SW,on}} = \frac{I_{\text{valley}} V_{\text{bulk,max}} \Delta t}{12} F_{\text{sw}} = \frac{1.56 \times 400 \times 45m}{12} \times 100k \approx 235 \text{ mW} \]  

**Page 869:** the word “to” is missing …an active clamp circuit to improve the converter’s…