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

Compilation of typos, mistakes and errors found by readers (or by the author himself)
First Edition

Chapter 1

Page xvi: Sorry Monsieur Balocco, your name was misspelled with two “l”. One is enough: Dr. Didier Balocco from Saft Power Systems.

Page 4: equation (1-1) result is incorrect, it should be 140 Ω (Fig. 1-1 is ok though)

Page 22: below equation (1-32): “for a buck, \( V_1 = V_{in} - V_{out} \) and not \( V_{out} - V_{in} \).
Contributed by C. Denton, March 2008.

Page 23: in Fig. 1-12a, you should read “boundary” conduction mode.
Contributed by Jason, May 2009

Page 40/41: in equation 1-83, I wrongly expressed the equality 1-83. The current starts from \(-\Delta I_L/2\) and needs to go back to that value. Therefore, the correct equation should be:

\[
-\frac{\Delta I_L}{2} = \frac{\Delta I_L}{2} - \frac{V_{out}}{L} t_{off} \quad (1-83)
\]

Re-arranging to extract \(\Delta I_L\) leads to

\[
\Delta I_L = \frac{V_{out}}{L} t_{off} \quad (1-84)
\]

Substituting Eq. (1-84) in Eq. (1-82) gives

\[
\Delta V = \frac{T_{sw} V_{out}}{8CL} t_{off} \quad (1-85)
\]

Knowing that \( t_{on} = DT_{sw} \) and \( t_{off} = (1-D)T_{sw} \) gives us a chance to massage equation 1-85:

\[
\Delta V = \frac{T_{sw}^2 V_{out} (1-D)}{8CL} \quad (1-86)
\]

\[
\ldots
\]

Replacing \( LC \) in equation 1-86 and introducing \( F_{sw} \), the switching frequency, it gives:

\[
\Delta V = \frac{\pi^2 T_{sw} L V_{out} f_{sw}^2 (1-D)}{2} \quad (1-89)
\]

To simplify this expression, a possibility exists to normalize the ripple to the output voltage, \( V_{out} \). Equation 1-89 can thus be updated as:
\[
\frac{\Delta V}{V_{\text{out}}} = \frac{\pi^2 T_{\text{sw}} f_0^2 (1-D)}{2}
\] 
(1-90)

Knowing that \( T_{\text{sw}} = \frac{1}{F_{\text{sw}}} \), it comes:

\[
\frac{\Delta V}{V_{\text{out}}} = \frac{\pi^2 f_0^2}{2} \left( \frac{f_0}{F_{\text{sw}}} \right)^2 (1-D) 
\] 
(1-91)

Contributed by Wolfgang Kostorz, January 2011

**Page 50:** In Figure 1-34, the lower curve is incorrectly labelled \( \tau = 0.01 \) whereas it should be \( \tau = 0.1 \).

Contributed by Wolfgang Kostorz, January 2011

**Page 57:** To gain a comprehensive understanding of the buck-boost operation… The word buck is missing.

Contributed by Kulsangcharoen Ponggorn, June 2008.

**Page 53:** In equation 1-126, the time “\( t \)” is missing in one of the terms. The correct equation should be:

\[
\frac{1}{C_0} \int_0^t I_c(t) \cdot dt = \frac{1}{C} \left[ \frac{\Delta I_L}{t_{\text{off}}} \left( t_{\text{off}} - \frac{t^2}{2} \right) + \frac{V_{\text{out}}}{R_{\text{load}}} \left( \frac{1}{D'} - 1 \right) t - \frac{\Delta I_L}{2} t \right] 
\] 
(1-126)

Contributed by Jason Canaday, July 2009

**Page 53:** In equation 1-125, the resistor is \( R_{\text{load}} \), not \( R \). The correct equation should be:

\[
I_c(t) = \Delta I_L \left[ \frac{t_{\text{off}} - t}{t_{\text{off}}} \right] + \frac{V_{\text{out}}}{R_{\text{load}}} \left[ \frac{1}{D'} - 1 \right] - \frac{\Delta I_L}{2}
\] 
(1-125)

Contributed by Jason Canaday, July 2009

**Page 69, figure 1-50:** I don’t know what happened to the captions on the graph, but those on the picture are certainly not at the right place. Here is the corrected graph:
Page 71: on page 71, in Figure 1-52, the top graph should be labeled 150 Ω and not 50 Ω.
Contributed by Michael Schutten, April 2010

Page 83: in step 4, you should read $I_{dc} = 144$ mA rms and not 13 mA rms. Same correction in step 5 where the 13 mA term must be replaced by 144 mA.
Contributed by Hong Gu, June 2009

Page 88: in the definition of the $A$ matrix, the coefficient $a_{12}$ should be divided by $C$ and not $L$:
$$A = \begin{bmatrix} \frac{-R_1R_2 + R_1R_3 + R_2R_4}{(R_2 + R_3)L} & \frac{-R_3}{(R_2 + R_3)L} \\ \frac{R_3}{(R_2 + R_3)C} & \frac{1}{(R_2 + R_3)C} \end{bmatrix}$$

The output current susceptibility is also affected by a sign typo:
$$T_{12}(s) = -\frac{R_1}{R_1 + R_2} \frac{1 + sR_3C}{s^2LC \left( \frac{R_3 + R_2}{R_1 + R_3} \right) + sL + C \left( \frac{R_2R_3 + R_2R_4 + R_3R_4}{R_1 + R_3} \right) + 1}$$

Contributed by Mitch Buchowiecki, Nov. 2009

Page 92, figure 1B-15: the upper curve caption should be “output step, 400 mA/µs” and not “stemp, 400 mA/ms”!

Page 92, figure 1B-15: the amplitude caption in the figure is wrong, the 2 mV does not make sense. The real capacitor contribution alone is 70 mV as corrected in the below figure.
Figure 1-B5: …step, $S_1 = 400 \text{ mA}/\mu\text{s}$ (not 450 mA)

Chapter 2

Page 109: in Eq. 2-54a, the minus sign has disappeared, you should actually read:

$$\dot{x}_1 = -\frac{1}{L} \ddot{x}_2 + \frac{D}{L} \ddot{u}_1 + \frac{\hat{d}}{L} u_{10}$$

Contributed by Johannes Eha, May 2009

Page 111: in Fig. 2-13, the right end of the x-axis should be labeled 100 kHz and not 110 kHz. Contributed by Thoralf Rosahl, Feb. 2009

Page 121: Figure 2-29, the parenthesis around $(R.d')$ are incorrect. As correctly indicated by 2-75 it should be $R.(d')^2$. Contributed by Dennis Cote, October 2011

Page 127: in equation (2-93), the $/D'^2$ has gone: $\frac{1}{sC/D'^2} + r_{lj}D'^2 = 0$

Contributed by Alain Laprade, January 2014

Page 129: In the text, “here we can read 335 mV or 33.5%” and not 419 mV or 41.9%. Contributed by Jie Yan, Feb. 2009

Page 129: the boost in CCM Bode plot does not include the ESR effects. The caption should then read: “Transfer function variations depending on the damping introduced by $r_{lf}$ with zero ESR”. Contributed by Thoralf Rosahl, May 2009

Page 152: Equation 2-137 should be $I_L(0) = -S_1 dT_{sw} + \ldots$ rather than $\Delta I_L(0) = -S_1 dT_{sw} + \ldots$

Contributed by Alex Kim, August 2009
Page 159: Equation 2-173 should be \( D_0 \frac{S_x}{S_z} \frac{S_x}{S_z} = D_0 - \frac{1}{2} \), leading to an updated equation 2-174:
\[
S_x = D_0 \left( D_0 - \frac{1}{2} \right).
\]
The conclusion in 2-175 is still correct.
Contributed by Ricard Takase, October 2011

Page 167, CCM PWM switch CM listing

A capacitor has been purposely added between terminals C and P to create the subharmonic effects at half of the switching frequency. To obtain exactly the same curve as with Ridley models, the capacitor must be connected after the voltage source VM, between nodes cx and p accounting for the presence of this capacitor in the measured current. It was previously connected between c and p, leading to a slight high-frequency deviation. The correction has been included before print, the book listing is thus good.

Page 174: Equation 2-205: the unit should be s not µs, 52.8 kV/s
Contributed by Hawk Shang, August 2009

Page 228: there are two small typos in equation (2A-9) and \( H_c \) definition:
\[
\frac{V_{out}(s)}{V_{err}(s)} = F_n H_c \frac{1 + \frac{s}{\omega_{p1}}}{1 + \frac{s}{\omega_{p1}}} \frac{1 + \frac{s}{\omega_{p2}}}{1 + \frac{s}{\omega_{p2}}} \quad \text{and} \quad H_c = \frac{2m V_{out}}{D} \frac{1 - M}{2m - (2 + m_c)M}
\]
Contributed by Hawk Shang, March 2010

Page 230: the definition for \( k_1 \) features \( M (1 - M) \). It should actually be \( M (M - 1) \).
Contributed by Thoralf Rosahl, May 2009

Page 235: in bullet 2: …sense resistor \( R_i \) to the secondary side via \( R' = NR_i \).
Contributed by YangFu, January 2013

Page 236: Eq. (2B-6) should be: \( T(t) = 1 - 2e^{-t} + e^{-2t} \)

Chapter 3

Page 245: In Fig. 3-5, the capacitor CoL should be 1 kF and not 1 kH.
Contributed by Aleksander Ansion, Feb. 2009

Page 256: the section header 3.5.5 should be better labeled “Type 2 Amplifier - Origin Pole plus Zero-Pole-Pair”
Contributed by Thoralf Rosahl, Feb. 2009

Page 264: in equation 3-27a, the compensator gain must be the opposite of that of the plant at the considered crossover frequency. Therefore, the equation must exhibit a minus sign in the exponent:
\[ G = 10^{G_r/s_0} \quad (3-27a) \]

Contributed by Pascal Fritz, 25/10/2012

**Page 268:** Fig. 3-22, page 268: in the picture, \( R_{load} \) should be 2.5 \( \Omega \) and not 2.5 W.
Contributed by C. Denton, March 2008.

**Page 269:** Fig. 3-23a, page 268: in the picture, \( f_c \) should be 5 kHz and not 5 Hz.
Contributed by C. Denton, March 2008

**Page 276:** Fig. 3-28, page 276: in the schematic parameters list, \( f_{p2} \) should be 50k and not 50.
Contributed by C. Denton, March 2008.

**Page 288:** The table describing the TL431 and TLV431 features an obvious typo. The breakdown voltage of the TLV431 is not 1 V but 18 V!

<table>
<thead>
<tr>
<th>Reference</th>
<th>Vref</th>
<th>Ibias, min</th>
<th>Precision</th>
<th>Max voltage</th>
<th>Max current</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL431I</td>
<td>2.495 V</td>
<td>1 mA</td>
<td>±2% @ 25 °C</td>
<td>36 V</td>
<td>100 mA</td>
</tr>
<tr>
<td>TL431A</td>
<td>2.495 V</td>
<td>1 mA</td>
<td>±1% @ 25 °C</td>
<td>36 V</td>
<td>100 mA</td>
</tr>
<tr>
<td>TL431B</td>
<td>2.495 V</td>
<td>1 mA</td>
<td>±0.4% @ 25 °C</td>
<td>36 V</td>
<td>100 mA</td>
</tr>
<tr>
<td>TLV431A</td>
<td>1.24 V</td>
<td>100 μA</td>
<td>±1% @ 25 °C</td>
<td>18 V</td>
<td>20 mA</td>
</tr>
<tr>
<td>TLV431B</td>
<td>1.24 V</td>
<td>100 μA</td>
<td>±0.5% @ 25 °C</td>
<td>18 V</td>
<td>20 mA</td>
</tr>
</tbody>
</table>

Contributed by Chalermkiat, June 2008.

**Page 293:** Fig. 3-39, page 293: in the schematic parameters list, it should be \( f_c = 1k \) and not just “1” and below should be \( \text{pm} = 100 \) and not \( \text{kpm} = 100 \).
Contributed by C. Denton, March 2008.

**Page 308:** In the text: …phase margin. And this IS an important point. The “is” is missing.
Contributed by Johannes Eha, July. 2012

**Page 349:** Equation 3-29 is obviously missing the imaginary operator:

\[
\arg(T(f))_{\text{boost}} = \arg \left( \frac{1 + \frac{f}{f_{c0}}}{1 + \frac{f}{f_{m0}}} \right) = \tan^{-1} \left( \frac{f}{f_{c0}} \right) - \tan^{-1} \left( \frac{f}{f_{m0}} \right)
\]

Contributed by Johannes Eha, July. 2012

**Page 289:** figure 3-37 \( k_1/k_2 \) coefficients are ok, just add a “-” sign to \( CTR*R_{\text{pullup}}/R_{\text{LED}} \).
Contributed by Simon, May. 2009

**Page 312:** “However, if the copper…” and not “it the copper…”
Contributed by Jie Yan, Feb. 2009

**Page 322:** Reference 3. “Note from the author: it’s too old, can’t find place…”. Obviously, this sentence was left over during the editing process!

**Page 331:** “…TL431’s ability…” and not “TL431’a ability…”
Contributed by Jie Yan, Feb. 2009

**Chapter 4**
Page 349: The in-line equation in 4.3 is wrong, as well as the reference in the text. It should be:

\[ B1 \text{ INT GND } V(\text{Vdum}) < 1.5 \text{m} \equiv (V_{\text{ref}} + V(\text{in})) \times 1.0 \text{m} \]

IF the output current is less than 1.5 mA THEN the source delivers \( V_{\text{ref}} + V(\text{in}) \times 1.0 \text{m} \) in series with a 2.5 \( \Omega \) resistor. The term \( V_{\text{ref}} + V(\text{in}) \times 1.0 \text{m} \) represents the \(-60 \text{ dB input susceptibility}.

Contributed by Johannes Eha, July 2012

Page 353: The PSpice code reproduced at the right bottom of the page should be:

\[ \text{GINT 0 INT} \]

and not \[ \text{BGINT 0 INT} \]

Contributed by Jie Yan, Feb. 2009

Page 359: The netlist is supposed to be a PSpice netlist, the in-line equation for \( B_1 \) is actually an IsSpice code. The correct version should be: \[ E1 \text{ If 0 Value = } \{ \text{IF (V(3,30)>5, 5, 0) } \} \]

Contributed by Jie Yan, Feb. 2009

Page 402: in equation 4B-11, the word open as slipped, it should be put besides \( \text{and the primary} \) of course.

Contributed by Jie Yan, Feb. 2009

Page 402: in equation 4B-12, the \( A \) should be \( A^2 \)

\[ L_{\text{21}} = L_1 - \sqrt{L_2 - L_1} - L_2 = L_4^2 + \frac{L_5}{A^2} = 58.5 \text{ }\mu\text{H} \]

Contributed by the author

Chapter 5

Page 411: “Numerical application gives a cutoff frequency of 54 kHz” and not 45 kHz.


Page 418, equation 5-17:

This equation defines the diode conduction losses by:

\[ P_{\text{cond,diode}} = V_f I_{d,\text{avg}} + R_d I_{d,\text{rms}}^2 \quad (5-17) \]

In the above expression, \( V_f \) should be replaced by \( V_{T0} \) where \( V_{T0} \) represents the threshold voltage of the junction. If you look at figure 1 (see the appendix at the end), the diode model appears on the right side. It combines a constant voltage source, \( V_{T0} \), in series with a dynamic resistor \( R_d \). The total voltage drop \( V_f \) measured at a given current \( I_{d0} \), combines \( V_{T0} \) and the dynamic resistor drop. If you use \( V_f \) as in Eq. (5-17), the term \( R_d \) is counted twice. Therefore, the total average power dissipated by the diode is correctly expressed by:

\[ P_{\text{cond}} = V_{T0} I_{d,\text{avg}} + R_d I_{d,\text{rms}}^2 \approx V_f I_{d,\text{avg}} \]

\( V_{T0} \) depends on the diode technology. It is measured when the diode starts conducting (a few hundred of \( \mu\text{A} \)). The drop is roughly 0.4 V for a Schottky and 0.6 V for a PN diode.

The correction is as follows:
… The conduction losses for a diode are given by

\[ P_{\text{cond}} = V_{T0} I_{d,\text{avg}} + R_d I_{d,\text{rms}}^2 \approx V_f I_{d,\text{avg}} \]  \hspace{1cm} (5-17)

where \( I_{d,\text{avg}} \) = average current in the diode
\( V_f \) = forward voltage at the considered diode current
\( V_{T0} \) = forward voltage at which the diode starts to conduct (\( \approx 0.4 \) V for a Schottky, \( \approx 0.6 \) V for a PN diode)
\( R_d \) = …..

Page 445: the first term of the formula 5-63 is wrong, the formula should be:

\[ f_0 = \frac{1}{2\pi \sqrt{L_C}} = \frac{1-D}{2\pi \sqrt{LC}} \]

Contributed by Jie Yan, Feb. 2009

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 456: the slope of (5-81) is obviously kV/s. Then \( D' \) is 1-\( D_0 \) so the denominator of (5-82) is (1-464m) and the result is 1.52. (5-83) updates to 284 kV/s and (5-84) is \( S' \) equal to 11.4 kV/s. The pole \( f_p \) is lightly affected and now it equals 357 Hz (replace \( x \) 1.76 by \( x \) 1.52). (5-86) updates to 223 kΩ.
Contributed at the last minute by Wayne Fit! January 2013.

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 460: in the sentence, the and is wrong: “we display the input current at low input voltage” and not “…and low input voltage.”
Contributed by Jie Yan, Feb. 2009

Page 467: in equation 5-98, the first denominator factor (0.1) needs to be 1:

\[ L = \frac{0.9 \times 15^2 \times 12^2}{1 \times 100 \times 24 \times (15+12) \times (12+0.9 \times 15)} = 17.6 \mu\text{H} \]

Contributed by Ektoras, April. 2013

Page 469: figure 5-14a:

The caption should say …The CCM buck-boost converter…

Chapter 6

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

\[ I_{d,\text{avg}} = \frac{P_{\text{conv}}}{2\eta V_{\text{bulk,avg}}} = 0.56 \text{ A} \hspace{1cm} (6-41b) \]
Page 513: in equation 6-59, the \( \text{rms} \) subscript is missing:

\[
P_{\text{in,apparent}} = V_{\text{rms}} \sqrt{\sum_{n=1}^{\infty} I_{n,\text{rms}}^2} = V_{\text{rms}} I_{\text{rms}}
\]

Contributed by Jie Yan, Feb. 2009

Page 514: “…extracting \( k_d \) from eq. (6-66)…” and not (6-67).

Contributed by Jie Yan, Feb. 2009

Page 562: equation 6-166

It should be \( R_1 \) not \( R_3 \):

\[
R_1 = \frac{275 \times \sqrt{2} - 3}{250 \mu} = 1.6 \text{ M}\Omega
\]

Chapter 7

Page 583: FIGURE 7-3a

The PWL definition in the figure should be: V2 4 0 Pulse 0 5 0 10n 10n 5u 10u


Page 586: FIGURE 7-4a

The PWL definition in the figure should be: V2 4 0 Pulse 0 5 0 10n 10n 5u 10u


Page 588: “…the equation affecting the plot n°3 in figure 7-4c should be: …+ \( V_{\text{in}} \) + \( V_{\text{leak}} \) and not \( V_{\text{teak}} \).

Contributed by Mohammad Monfared, Nov. 2009

Page 623: equation 7-79 should be:

\[
V_{DS} = V_{\text{in}} + \frac{V_{\text{out}} + V_{f}}{N} + V_{\text{leak}}
\]

Contributed by Mohammad Monfared, Nov. 2009

Page 623: in equation 7-80, the right term must be multiplied by \( F_{\text{sw}} \):

\[
V_{DS} = V_{\text{in}} + \frac{V_{\text{in}} + V_{f}}{N} + \frac{2L_{\text{sw}} P_{\text{sw}} F_{\text{sw}}}{\eta V_{\text{in,\text{max}}} D_{\text{min}} (1 - D_{\text{min}})}
\]

Contributed by Zaikin Denis, Dec. 2009

Page 624: in equation 7-88, the right term must be multiplied by \( F_{\text{sw}} \):

\[
V_{C_{\text{in,\text{max}}}} = \frac{V_{\text{in}} + V_{f}}{N} + \frac{2L_{\text{sw}} P_{\text{sw}} F_{\text{sw}}}{\eta V_{\text{in,\text{max}}} D_{\text{min}} (1 - D_{\text{min}})}
\]

\[
= 19 + 1 + 2 \times 20 \mu \times 76 \times 65 k \times \frac{1}{0.166} + 0.85 \times 370 \times 0.236 \times (0.764) = 124 \text{ V}
\]

Contributed by Zaikin Denis, Dec. 2009

Page 633: voltage-mode control table
The dc gain, $V_{out}/V_{error}$, should be:

$$\frac{NV_{in}}{(1-D)^2 V_{peak}}$$

Page 646: the notation for the current is misleading. Rather than $I_{CV_{ce}}$ it should be $I_{CV_{ce}}$
Contributed by Jie Yan, Feb. 2009

Page 647: in equation 7-116 it should be $V_{ac, peak}$ and not $V_{act}$...
Contributed by Mohammad Monfared, Nov. 2009

Page 651: in equation 7-127, the term $V_{bulk, max}$ is missing in the middle of the equation. It should be:

$$P_{DSS} = I_{CC} V_{bulk, max} = (I_s + Q_{F_e}) V_{bulk, max} = ...$$

Contributed by Mohammad Monfared, Nov. 2009

Page 652: …below 15 V, then there is no arm to let the driver…→ there is no harm!
Contributed by C. Denton, April 2008.

Page 660: in figure 7-52, the label on the upper left corner should be Ls and not Laux.
Contributed by Mohammad Monfared, Nov. 2009

Page 663: after (see Early effect). With an output…
Contributed by Mohammad Monfared, Nov. 2009

Page 663: “…if the controller hosts…” and not “…it the controller…”
Contributed by Jie Yan, Feb. 2009

Page 679, equation 7-166:

$$P_d = V_T I_d_{avg} + R_d I_d_{rms}^2 + D I_R PIV = V_f I_d_{avg} \quad (7-166)$$

Page 693, equation 7-204:

$$P_d = V_T I_d_{avg} + R_d I_d_{rms}^2 + D I_R PIV = V_f I_d_{avg} \quad (7-204)$$

Page 705: In Fig. 7-85, the emitter U1 (the optocoupler) should of course go the primary ground and not the secondary one!
Contributed by Aleksander Ansion, Feb. 2009

Page 712: Below equation 7-252: … selecting a 860 µH inductor and not indicator…
Contributed by Simon Buchwald, June. 2009

Page 713: Figure 7-90 vertical axis: $P_{out}$ must be replaced by $P(W)$
Contributed by Boris Popov, December 2012

Page 726: bullet 1, …for a given printed circuit board (pcb) area.
Contributed by Mohammad Monfared, Nov. 2009

Chapter 8

Page 765: Equation 8-24 has an extra letter for the $C_{lump}$ term. It should read:
\[ P_{sw,\text{lump}} = \frac{1}{2} C_{\text{lump}} V_{in}^2 F_{sw} \quad (8-24) \]

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:

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

Contributed by Prapat Chumchairat, 30/8/2008

**Page 809**: in fig. 8-50, the label in the right bottom should be \( (1-d)T_{\text{sw}} \) and not \( (1-d)dT_{\text{sw}} \).

Contributed by Jie Yan, Feb. 2009

**Page 810**: in fig. 8-51, the label in the lower left side be \( N_{s_1} = \frac{N_{s_2}}{n} \) and not \( N_{s_1} = nN_{s_2} \).

Contributed by John Tsinetakes, Dec. 2011

**Page 825, table 8-2**: In the “where” section, the definition for \( S_n \) has to be changed:

\[ S_n = \frac{N V_{in} - V_{out}}{L} N R_{\text{sense}} \]  \( \text{this is the on-time secondary slope reflected to the primary.} \)

The equation given in the page, \( S_n = \frac{V_{in}}{L_p} R_{\text{sense}} \), corresponds to the magnetizing current slope.

It can, by the way, be considered as a free external ramp.

**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:

\[
V_1 = L_1 \frac{dI_{s_1}}{dt} + M \frac{dI_{s_2}}{dt} = L_1 S_1 + M \cdot S_2
\]

\[
V_2 = L_2 \frac{dI_{s_2}}{dt} + M \frac{dI_{s_1}}{dt} = L_2 S_2 + M \cdot S_1
\]

Where \( S \) is current slope in each inductor and \( M \) represents the mutual inductance defined by:

\[ M = k \sqrt{L_1 L_2} \]  \( \text{with } k \text{ the coupling coefficient} \)

Solving for the respective slopes:
We know that $N$ turns wound on a magnetic medium affected by a specific inductor factor $A_i$ give an inductor $L$ equal to: $L = A_i N^2$

$L_1 = N_{l1}^2 A_i$ and $L_2 = N_{l2}^2 A_i$

$M = k \sqrt{L_1 L_2} = k N_{l1} N_{l2} A_i$

For proper current balance in the coupled inductors, we have $\frac{N_{l2}}{N_{l1}} = \frac{N_2}{N_1}$. Therefore,

$N_{l2} = \frac{N_2}{N_1} N_{l1}$, where $N_1$ and $N_2$ are the turns ratios of the forward transformer respectively delivering $V_{o1}$ and $V_{o2}$, where $N_{l1}$ and $N_{l2}$ are the turns ratios of the coupled inductors.

Substituting the above in $M$ gives us:

$M = k N_{l1} \frac{N_2}{N_1} N_{l1} A_i = k N_{l1}^2 \frac{N_2}{N_1} A_i$

In CCM, both output voltages are linked by a coefficient $\alpha$

$N_2 = \alpha N_1$ and $V_{o2} = \alpha V_{o1}$

The voltage across the inductors is defined by:

$V_2 = V_m N_2 - V_{o2}$ and $V_1 = V_m N_1 - V_{o1}$

$M$ can be updated to become: $M = k N_{l1}^2 \frac{\alpha N_1}{N_1} A_i = k N_{l1}^2 \alpha A_i$

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

$V_2 = V_{o2} \alpha N_1 - \alpha V_{o1} = \alpha \left( N_1 V_m - V_{o1} \right)$

$L_2 = (N_{l2} \alpha)^2 A_i$

Substituting the above in the first transformer definitions leads us to:

$S_1 = -\frac{V_{o1} - N_1 V_m}{A_i N_{l1}^2 (k + 1)}$ and $S_2 = -\frac{V_{o1} - N_1 V_m}{A_i N_{l1}^2 \alpha (k + 1)}$

The primary reflected slope is simply the sum of the individual slopes:
\[ S_p = s_1N_1 + S_2N_2 \]

We know that \( N_2 = \alpha N_1 \), therefore: \( S_p = N_1 \left( s_1 + \alpha S_2 \right) \). Finally, we have:

\[
S_p = -\frac{2N_1(V_{in} - N_1V_m)}{A_1N_1^2(k+1)} \quad \text{by replacing } A_1N_1^2 \text{ by } L_1 \text{ and divided by } N_1, \text{ we have:}
\]

\[
S_p = \frac{V_m - V_{al}}{N_1^2} \frac{L_1}{k+1} \quad \text{from which we can extract the equivalent inductor seen from the primary:}
\]

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

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

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

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:

\[ P_{cond} = I_{p,\text{rms}}^2 R_{DS(on)} \oplus T_j = \ldots \quad (8-124) \]

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:

\[
P_{SW,\text{on}} = \frac{I_{valley} V_{\text{bulk,max}} \Delta t}{12} \frac{F_{sw}}{12} = \frac{1.56 \times 400 \times 45}{12} \times 100k = 235 mW \quad (8-125c)
\]

Page 834: small typo on the current \( I_{valley} \) (or \( I_{peak} \)) should be \( I_{p,\text{valley}} \) or \( I_{p,\text{peak}} \):

\[
P_{SW,\text{on}} = \frac{I_{p,\text{valley}} V_{\text{bulk,max}} \Delta t}{12} \frac{F_{sw}}{12} \quad \text{eq. 8-125a}
\]

\[
P_{SW,\text{on}} = \frac{I_{p,\text{valley}} V_{\text{bulk,max}} \Delta t}{12} \frac{F_{sw}}{12} = \frac{1.56 \times 400 \times 45}{12} \times 100k = 235 mW \quad \text{eq. 8-125c}
\]
\[ P_{SW,off} = \frac{I_{p,peak} V_{bulk} \Delta t}{2} F_{sw} \quad \text{eq. 8-125d} \]

\[ P_{SW,off} = \frac{I_{p,peak} V_{bulk,max} \Delta t}{2} F_{sw} = \frac{1.84 \times 400 \times 45n}{2} \times 100k = 1.65 \text{ W} \quad \text{eq. 8-125e} \]


**Page 838:** the formula 8-137 has to be updated since eq. 8-125C delivers 235 mW and not 470 mW: \[ P_{\text{tot}} = P_{\text{cond}} + P_{SW,\text{on}} + P_{SW,\text{off}} = 1 + 0.235 + 0.48 \approx 1.715 \text{ W} \]

Contributed by Jie Yan, Feb. 2009

**Page 856:** equation 8B-12

The equation should be: \[ C_{eq} = C_{L2} \left( \frac{N_3}{N_2} \right)^2 \parallel C_{L1}, \] the \( C_{L2} \) sub term is missing.

For equations 8B-13c and 8B-13d, \( F_{sw} \) should be replaced by \( f \), where \( f \) is a sinusoidal signal of course.

**Page 860:** equation 8C-2

In the numerical application, the \( 10^4 \) is gone, but the result is correct:

\[ W_{a} A = \frac{P_{out}}{K_{K,B_{max}} F_{sw} J} 10^4 \approx \frac{250 \times 10000}{507 \times 0.0005 \times 0.11 \times 100000 \times 400} = 2.24 \text{ cm}^4 \quad \text{eq. 8C-2} \]


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