Designing Control Loops for Linear and Switching Power Supplies: A Tutorial Guide – 2nd print

Christophe Basso – April 2014
Last update February 2026

Corrections of typos, mistakes and errors found by readers or by the author himself.

Page 12: figure 1.13, a “-“ sign is missing at the end of the vertical arrow, below the first summation circle.
Contributed by Ken Shirriff, April 2014

Page 13: …value. After a certain time designated as…
Contributed by Ken Shirriff, April 2014

Page 13: …be approximated by a linear system…
Contributed by Ken Shirriff, April 2014

Page 16: a possible test fixture... not text fixture
Contributed by Ken Shirriff, April 2014

Page 16: figure 1.17, …(amplitude-phase couples) are recorded at each frequency step.
Contributed by Ken Shirriff, April 2014

Page 17: The decibel, one tenth of a bel not a bell.
Contributed by Ken Shirriff, April 2014

Page 17: …compress the *x* and *y* axes.
Contributed by Ken Shirriff, April 2014

Page 17: End of the page: … the ratio increase between the second point and the starting point.
Contributed by Ahmed Yousef, September 2015

Page 18: …the corner frequency is the frequency at which the transfer function magnitude...
Contributed by Ken Shirriff, April 2014

Page 18: above equation (1.18), last bullet:…in other words,

$$S=\frac{y_2-y_1}{x_2-x_1}=\frac{y_2-y_1}{\log_{10}f_2-\log_{10}f_1} \qquad (1.18)$$

(1.19) needs an update as well:

$$S=\frac{-20}{\log_{10}\left(\frac{10f_1}{f_1}\right)}=-20\,\mathrm{dB/dec} \qquad (1.19)$$

Page 19: …of its terminal’s voltage (actually…
Contributed by Ken Shirriff, April 2014

Page 19: Second paragraph: A first-order system exhibits an up or down slope of 1 or -1, respectively, implying…
Contributed by Ahmed Yousef, September 2015

Page 20: …into a two-dimensional plane, the complex…
Contributed by Ken Shirriff, April 2014

Page 20: …and $Y(s)$ are functions of a complex…
Contributed by Ken Shirriff, April 2014

Page 20: …that positive time only *remove comma* is considered (the function is said…)
Contributed by Ken Shirriff, April 2014

Page 22: Figure 1.20: …by s after going through…
Contributed by Ken Shirriff, April 2014

Page 25: Figure 1.22: capacitor C_1 should be 0.1 µF in the Mathcad sheet.
Contributed by Ken Shirriff, April 2014

Page 26: Figure 1.24: when combining asymptotic responses,…
Contributed by Ken Shirriff, April 2014

Page 52: in Figure 2.16, all subscripts should be s_p and not s_z.
Contributed by Martin Svensson, April 2014

Page 48: In equation (2.90), the real parts have to be updated when the capacitor ESR goes to zero:

$$s_1 = -4.8k + j31.4k$$
$$s_2 = -4.8k - j31.4k$$

Contributed by Ahmed Yousef, September 2015

Page 48: As a result, the resonant frequency definition must also change but the result is unaffected:

$$\omega_0 = |s_1| = |s_2| = \sqrt{(4.8k)^2 + (31.4k)^2} = 31.73 \text{ krd/s or } 5.05 \text{ kHz}$$

Contributed by Ahmed Yousef, September 2015

Page 51: End of bullet 4: It is important to note that if the real part is 0, we have imaginary pole pairs of the form $p_i = \pm j\omega$.
Contributed by Ahmed Yousef, September 2015

Page 55: 3rd paragraph, second line: …move to the right-half-*plane* section.
Contributed by Felix Lieberium, July 2022

Page 57: above (2.105) of course, “surface” has a different meaning in English: …circulating in the load is the area of A_0, averaged…

Page 58: below Figure 2.22: In theory, the new *area*, A_1, should be…

Page 60: a typo in (2.113), the square in the denominators is missing.

$$\Delta I_L = \frac{V_{in}}{R_{load}}\left[\frac{1}{(1-D_1)^2} - \frac{1}{(1-D_0)^2}\right] = \frac{10}{240}\left[\frac{1}{(1-0.59)^2} - \frac{1}{(1-0.583)^2}\right] = 8.25\text{ mA}$$

$$dt = \frac{8.25m}{160u} = 51.6\ \mu\text{s}$$

In the text below, replace 10.6 µs by 51.6 µs.
Contributed by Orestis Polychronakis, February 2015

Page 60: below (2.112): Brought back to the inductor *current* change…
Contributed by Felix Lieberium, July 2022

Page 86: figure 3.9: the shift in magnitude is closer to 20 dB than 25.
Contributed by Felix Lieberium, July 2022

Page 89: Line 2: In ~~a~~ many theory books, …
Contributed by Felix Lieberium, July 2022

Page 128: don't know why the 3 disappeared in expression (3.149):

$$-\omega\tau \approx -2\left[\frac{\omega}{\omega_\tau} - \frac{\left(\frac{\omega}{\omega_\tau}\right)^3}{3} + \frac{\left(\frac{\omega}{\omega_\tau}\right)^5}{5}\right]$$

Contributed by Jobe Chen, June 2020

Page 145: in equation (3.189), the term $V_{out}(s)$ has disappeared from the equation:

$$\frac{V_{err}(s)}{V_{out}(s)} = -\frac{Z_f(s)}{R_{upper}}$$

Contributed by T L, September 2022

Page 159: the denominator in equation (4.2) is not homogeneous and the ω_{p1} term has to go:

$$N = \frac{\omega_{p_1}{}^2}{\omega_{p_1}\omega_{z_1} + \omega_{p_1}\omega_{z_2} - \omega_{z_1}\omega_{z_2}} - 1$$

This is a typo and the rest of the formulas is sound.

Page 194: a square is missing in the numerator and the division is by 2 to comply with the SPICE simulation. The final result is correct though:

$$|H(10k)| = H_0 \frac{\sqrt{1+\left(\frac{f_c}{f_{z_1}}\right)^2}}{\sqrt{\left(1-\frac{f_c^2}{f_0^2}\right)^2 + \left(\frac{f_c}{f_0 Q}\right)^2}} = \frac{10}{2}\frac{\sqrt{1+\left(\frac{10k}{10.3k}\right)^2}}{\sqrt{\left(1-\frac{10k^2}{1.24k^2}\right)^2 + \left(\frac{10k}{1.24k\times 1.45}\right)^2}} = 0.108\text{ or } -19.3\text{ dB}$$

Contributed by Jerry, July 2022

Page 215: equation (4.156) is suspicious. I actually took it from the paper referenced in [8] and included it without thinking it could be wrong. If you replace the definitions of the terms in a as defined page 214, you find a equals 0. I was alerted by a student, Siyu He, about this strange result and I decided to re-derive the equation myself. Develop (4.153) and rearrange the polynomial form, factoring s and s^2. You should find

$$G(s)=\frac{R_0-r_C}{H_0 r_C}\frac{1+s\left(\dfrac{QR_0\omega_0\omega_{z_1}-r_C\omega_{z_1}\omega_{z_2}+QR_0\omega_0\omega_{z_2}}{Q\omega_0\omega_{z_1}\omega_{z_2}\left(R_0-r_C\right)}\right)+s^2\dfrac{R_0\omega_0{}^2-r_C\omega_{z_1}\omega_{z_2}}{\omega_0{}^2\omega_{z_1}\omega_{z_2}\left(R_0-r_C\right)}}{1+s\left(\dfrac{H_0 Q r_C\omega_0{}^2\omega_{z_2}}{H_0 Q r_C\omega_0{}^2\omega_{z_1}\omega_{z_2}}\right)}$$

after simplification we have

$$G(s)=\frac{R_0-r_C}{H_0 r_C}\frac{1+s\left(\dfrac{QR_0\omega_0\omega_{z_1}-r_C\omega_{z_1}\omega_{z_2}+QR_0\omega_0\omega_{z_2}}{Q\omega_0\omega_{z_1}\omega_{z_2}\left(R_0-r_C\right)}\right)+s^2\dfrac{R_0\omega_0{}^2-r_C\omega_{z_1}\omega_{z_2}}{\omega_0{}^2\omega_{z_1}\omega_{z_2}\left(R_0-r_C\right)}}{1+\dfrac{s}{\omega_{z_1}}}=K_0\frac{1+a_1 s+a_2 s^2}{1+\dfrac{s}{\omega_{z_1}}}$$

Considering a dominant low-frequency pole given by $1/a_1$, then the numerator simplifies to

$$G(s)\approx K_0\frac{1+s\left(\dfrac{R_0\left(\omega_{z_1}+\omega_{z_2}\right)}{\omega_{z_1}\omega_{z_2}\left(R_0-r_C\right)}\right)}{1+\dfrac{s}{\omega_{z_1}}}=K_0\frac{1+\dfrac{s}{\omega_{z_G}}}{1+\dfrac{s}{\omega_{p_G}}}$$

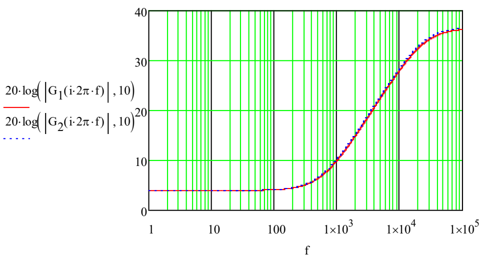
with

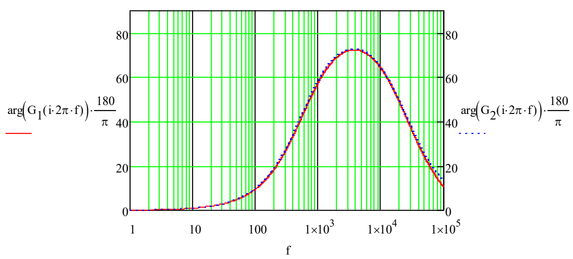
$$K_0=\frac{R_0-r_C}{H_0 r_C}$$

$$\omega_{z_G}=\frac{\omega_{z_1}\omega_{z_2}}{\omega_{z_1}+\omega_{z_2}}\frac{R_0-r_C}{R_0}$$

$$\omega_{pG}=\omega_{z_1}$$

The response comparing (4.153) in $G_1(s)$ and the above equation in $G_2(s)$ is shown below





Motivated by Siyu He, April 2015

Page 273: above 5.5.3: …of the whole chain ~~in~~ is now 90°…
Contributed by Felix Lieberium, July 2022

Page 286: Equation (5.127) returns a wrong value:

$$G_2 = \frac{10^{\frac{-10}{20}}}{0.88} = 0.359 \qquad (5.127)$$

And the two equations below then need an update also:

$$R_2 = R_1 G_2 = 38k \times 0.359 = 13.6\ \text{k}\Omega \qquad (5.128)$$

$$C_1 = \frac{1}{2\pi f_z R_2} = \frac{1}{6.28 \times 1.8k \times 13.6k} = 6.5\ \text{nF}\ (5.129)$$

Contributed by Dmitriy, March 2020

Page 325: equation (5.282), the value for the pole in C_2 equation is f_{p1}

$$C_2 = \frac{1}{2\pi R_{pullup} f_{p_1}} \quad (5.282)$$

Contributed by X.H Zhu, October 2023

Page 327: equation (5.294), the value for the pole in C_2 equation is f_{p1} but the value is unchanged as the 2 poles are coincident.
Contributed by X.H Zhu, October 2023

Page 330: equation (5.301), this is $V_{err}(s)/V_{out}(s) = \ldots$ and not $V_{op}(s)/V_{out}(s)$
Contributed by Raymond Carr, July 2014

Pages 339/340: the value for the pole in C_2 equation is f_{p1}

Page 364: The selected OTA offers a 100-µS transconductance and not 199-µS
Contributed by Dmitriy, March 2020

Page 398: The R_{LED} maximum value…
Contributed by Felix Lieberium, July 2022

Page 400: The capacitor in formula (7.41) is C_2 not C_1

$$V_{err}(s) = -I_C(s)\frac{R_{pullup}\frac{1}{sC_2}}{R_{pullup} + \frac{1}{sC_2}} = -I_C(s) R_{pullup} \frac{1}{1 + sR_{pullup}C_2}$$

Contributed by Felix Lieberium, July 2022

Page 417: figure 7.25, the magnitude and phase are read at 20 Hz, not 1 kHz.

$$\left|G(20\ \text{Hz})\right| = -18.8\ \text{dB} \text{ and } \arg G(20\ \text{Hz}) = -213°$$

Contributed by Nicola Rosano, May 2020

Page 421: it is f_{p1} in (7.114)

$$C_2 = \frac{1}{2\pi R_{pullup} f_{p_1}}$$

Page 421: it is f_{p1} in (7.124)

$$C_2 = \frac{1}{2\pi R_{pullup} f_{p_1}} = \frac{1}{6.28 \times 20k \times 3.7k} = 2.15\ \text{nF}$$

Page 430: there is one typo in the application equation but those shown in Figure 7.33 macro are correct. The error lies in the value passed for G in (7.153). It should be 0.316 which corresponds to the 10-dB attenuation wanted at crossover.

$$R_2 = \frac{0.316 \times 38k \times 1.8k}{20k \times 0.3} \times \frac{\sqrt{1+\left(\frac{1k}{4.5k}\right)^2}\sqrt{1+\left(\frac{1k}{4.5k}\right)^2}}{\sqrt{1+\left(\frac{221}{1k}\right)^2}\sqrt{1+\left(\frac{1k}{221}\right)^2}} = 799\ \Omega \quad (7.153)$$

$$C_1 = \frac{1}{2\pi f_{z_1} R_2} = \frac{1}{6.28 \times 221 \times 799} \approx 900\ \text{nF} \quad (7.155)$$

$$C_2 = \frac{1}{2\pi f_{p_1} R_{pullup}} = \frac{1}{6.28 \times 4.5k \times 20k} \approx 1.8\ \text{nF} \quad (7.156)$$

After several exchanges with Nicola and Dmitriy! The Mathcad sheet shows the values and the final Bode plot:

------------- Components calculation according to the book, p429 ----------

$boost := 130°$ $R_1 = 38 \cdot k\Omega$ $R_{LED} := 1.8k\Omega$ $R_{pullup} = 20 \cdot k\Omega$ $CTR = 0.3$ G_f

$$G := 10^{-\left(\frac{G_{fc}}{20}\right)} = 0.316$$

$$f_{p12} := \frac{f_c}{\tan\left(45° - \frac{boost}{4}\right)} = 4.511 \cdot kHz$$

$$f_{z12} := \frac{f_c^{\,2}}{f_{p12}} = 221.695 \cdot Hz$$

$f_{p1} := f_{p12} = 4.511 kHz$ $f_{z1} := f_{z12} = 221.695 Hz$

$f_{p2} := f_{p12} = 4.511 kHz$ $f_{z2} := f_{z12} = 221.695 Hz$

$$R_2 := \frac{G \cdot R_1 \cdot R_{LED}}{R_{pullup} \cdot CTR} \cdot \frac{\sqrt{1+\left(\frac{f_c}{f_{p1}}\right)^2} \cdot \sqrt{1+\left(\frac{f_c}{f_{p2}}\right)^2}}{\sqrt{1+\left(\frac{f_{z1}}{f_c}\right)^2} \cdot \sqrt{1+\left(\frac{f_c}{f_{z2}}\right)^2}} = 799.208\Omega$$

$$R_3 := \frac{R_1 \cdot f_{z2}}{f_{p2} - f_{z2}} = 1.964 k\Omega$$

$$C_1 := \frac{1}{2 \cdot \pi \cdot f_{z1} \cdot R_2} = 898.266 \cdot nF$$

$$C_2 := \frac{1}{2 \cdot \pi \cdot f_{p1} \cdot R_{pullup}} = 1.764 \cdot nF$$

$$C_3 := \frac{f_{p2} - f_{z2}}{2 \cdot \pi \cdot R_1 \cdot f_{p2} \cdot f_{z2}} = 17.964 \cdot nF$$

$$G_{00} := \frac{R_2 \cdot R_{pullup} \cdot CTR}{R_{LED} \cdot R_1} = 0.07$$

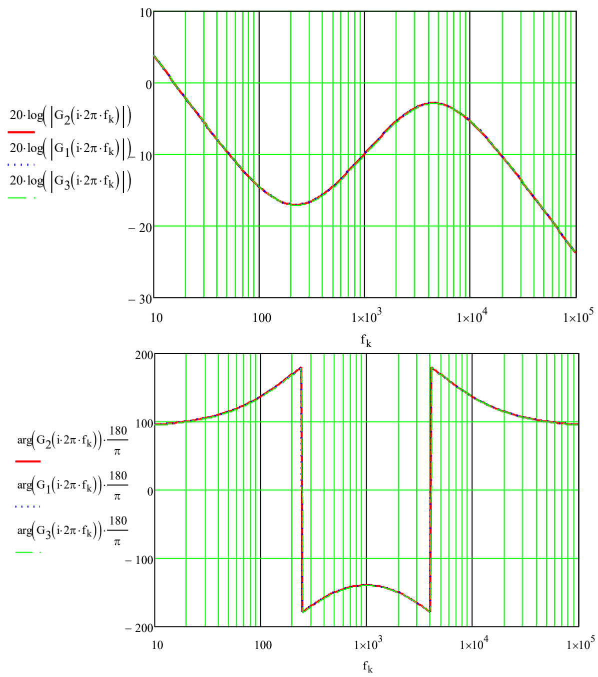
$$G_2(s) := -\frac{R_2 \cdot R_{pullup} \cdot CTR}{R_{LED} \cdot R_1} \cdot \frac{\left(1 + \frac{1}{s \cdot R_2 \cdot C_1}\right) \cdot \left[1 + s \cdot C_3 \cdot (R_1 + R_3)\right]}{(1 + s \cdot R_{pullup} \cdot C_2) \cdot (1 + s \cdot R_3 \cdot C_3)} \qquad f_c := 1kHz$$

$$20 \cdot \log\left(\left|G_2(i \cdot 2\pi \cdot f_c)\right|\right) = -10 \qquad \operatorname{atan}\left(\frac{f_c}{f_{z1}}\right) + \operatorname{atan}\left(\frac{f_c}{f_{z2}}\right) - 2 \cdot \operatorname{atan}\left(\frac{f_c}{f_{p12}}\right) = 130 \cdot °$$

$$f_{z1a} := \frac{1}{2 \cdot \pi \cdot R_2 \cdot C_1} = 221.695 Hz \qquad f_{z2a} := \frac{1}{2 \cdot \pi \cdot C_3 \cdot (R_1 + R_3)} = 221.695 Hz$$

$$f_{p1a} := \frac{1}{2 \cdot \pi \cdot R_{pullup} \cdot C_2} = 4.511 kHz \qquad f_{p2a} := \frac{1}{2 \cdot \pi \cdot R_3 \cdot C_3} = 4.511 kHz$$

$$G_3(s) := -G_{00} \cdot \frac{1 + \frac{2 \cdot \pi \cdot f_{z1}}{s}}{1 + \frac{s}{2 \cdot \pi \cdot f_{p1}}} \cdot \frac{\left(1 + \frac{s}{2 \cdot \pi \cdot f_{z2}}\right)}{\left(1 + \frac{s}{2 \cdot \pi \cdot f_{p2}}\right)}$$



The formulas were good in the IsSpice sheet but went wrong once copied in the book.

Page 445: in Figure 7.47 and Figure 7.48, the resistance involved in calculating C_{opto} is R_{pullup} considering the configuration.

Contributed by Felix Lieberium, July 2022

Page 506: 8th line: …characterize the other one (*fast* lane) by…

Page 532: equation (9.78), a square is missing in the denominator

$$|H(f)| = 20\text{Log}_{10}\left[H_0\frac{\sqrt{1+\left(\frac{f}{f_{z_1}}\right)^2}\sqrt{1+\left(\frac{f}{f_{z_2}}\right)^2}}{\sqrt{\left(1-\left(\frac{f}{f_0}\right)^2\right)^2+\left(\frac{f}{f_0 Q}\right)^2}}\right]$$

Contributed by Edwin Marte, April 2015

Page 534: equation (9.85) went wrong and should be corrected:

$$|G(f)| \approx 20\cdot\text{Log}_{10}\left[\frac{R_2}{R_1}\frac{\sqrt{1+\left(\frac{f_{z_1}}{f}\right)^2}\sqrt{1+\left(\frac{f}{f_{z_2}}\right)^2}}{\sqrt{1+\left(\frac{f}{f_{p_1}}\right)^2}\sqrt{1+\left(\frac{f}{f_{p_2}}\right)^2}}\right]$$

Contributed by Raymond Carr, October 2014