Application Note 44a

Type II Stability Program for the MIC2168/69

Stability Analysis for the MIC2168/69 Voltage Mode Converter Using a Type II Transconductance Error Amplifier

The MIC2169 is a high efficiency, simple to use synchronous buck controller IC, housed in a 10-pin MSOP package. The MIC2169 switches at 500kHz and features a high output driver capability for an all N-Channel synchronous architecture. The MIC2169 operates from a 3V to 13.2V input and can be configured to generate output voltages as low as 0.8V. Thus, the MIC2169 is a voltage mode converter with an internal transconductance error amplifier.

This application note addresses stability analysis for the MIC2169 voltage mode controller based on Dean Venable's K[1]-factor method. The following analysis is based on a Type II error amplifier scheme that calculates the compensation resistor and capacitors for the MIC2169 controller, see Figure 1. Type II error amplifier compensation scheme relies on the output capacitor ESR to produce a Zero in the power path (input to output) transfer function. For additional information on this subject, consult reference 2.

Type II compensation analysis is done in MathCad that gives the user the flexibility to enter the output capacitance value and ESR; inductor's value and its DCR to match the actual values used on a specific MIC2169 application. This program not only calculates the Compensation values but also gives lot of insight on how the values affect the overall open loop response. It also has the power-path and error-amplifier transfer functions that show the location of poles and zeros. The MathCad file can be downloaded from Micrel Semiconductor's website (URL:www.micrel.com/xyz/typeII.mcd). This program can be modified to any fit any voltage mode controller with a transconductance error amplifier by simply changing the gm (error amplifier gain) and the peak magnitude of the voltage ramp signal value.

The following values have to be entered in the program before it calculates the Compensation resistor, R1 and capacitors C1 and C2, see Figure 1:

1. V_{IN}
2. V_{OUT}
3. C_{OUT}
4. C_{OUT_ESR}
5. Inductor Value
6. DCR of inductor + R_{DSON} of upper MOSFET
7. Crossover Frequency (normally 50kHz)
8. Required Phase Margin (normally 45°-60°)

After entering the above values the program calculates the Compensation values and displays the power-path gain and phase, error amplifier gain and phase and total open-loop response gain and phase for the circuit. The program will also display the crossover frequency and phase margin for the calculated Compensation values:

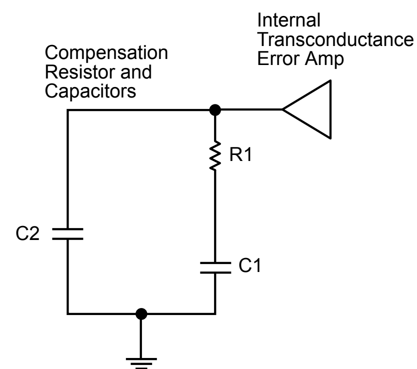

Figure 1. Type II Error Amplifier Scheme

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$L := 2.5\mu H$ Enter inductor value.

$C := 300\mu F$ Enter output capacitor value.

$ESR := 0.030\Omega$ Enter ESR for output capacitor.

$DCR := 0.025\Omega$ Enter inductor DC resistance+ Top MOSFET R_{DS_ON}.

$f_c := 50 \times kHz$ Choose crossover frequency.

$$f_{esr} := \frac{1}{2 \times \pi \times C \times ESR}$$

$V_{IN} := 5V$ Enter input voltage.

$V_{OUT} := 3.3V$ Enter output voltage.

$$D := \frac{V_{OUT}}{V_{IN}}$$

$$G_S := 20 \times \log\left[\left(\frac{0.8 \times V}{V_{OUT}}\right) - 0\right] \qquad G_S = -12.308$$

Feedback divider attenuation.

$$G_m := 20 \times \log\left(\frac{V_{IN} \times 1}{1V}\right)$$

Modulator gain.

Gm = 13.979

$$G_{(s)} := \frac{\left(\frac{1}{s \times C} + ESR\right)}{\left(DCR + s \times L + \frac{1}{s \times C} + ESR\right)}$$

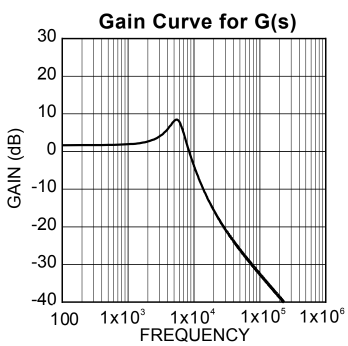
Power path transfer function.

$$G_{(s)} := \frac{(1 + ESR \times s \times C)}{(DCR \times s \times C + s^2 \times L \times C + 1 + ESR \times s \times C)}$$

Power path transfer function simplified.

Transfer function used for plotting gain curve in dB.

$$G(f) := G_s + Gm + 20 \times \log\left[\sqrt{1 + (ESR \times C \times 2 \times \pi \times f)^2}\right] - 20 \times \log\left[\sqrt{\left[1 - (2 \times \pi \times f)^2 \times L \times C\right]^2 + \left[2 \times \pi \times f \times C \times (ESR + DCR)\right]^2}\right]$$



$Mag := G(f_c)$ Mag is the amplitude of gain required at crossover from the error amplifier.

$Mag = -26.08$

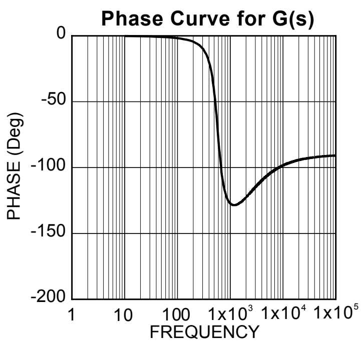
Phase Denominator- due to the LC of the output stage.

$$\phi(f) := \begin{cases} \left[57.3 \times \operatorname{atan}\left[\dfrac{2 \times \pi \times f \times C \times (ESR + DCR)}{\left|1 - (2 \times \pi \times f)^2 \times L \times C\right|}\right]\right] & \text{if } \left[(2 \times \pi \times f)^2 \times L \times C\right] < 1 \\ \left[180 - 57.3 \times \operatorname{atan}\left[\dfrac{2 \times \pi \times f \times C \times (ESR + DCR)}{\left[\left|1 - (2 \times \pi \times f)^2 \times L \times C\right|\right]}\right]\right] & \text{if } \left[(2 \times \pi \times f)^2 \times L \times C\right] > 1 \\ 90 & \text{otherwise} \end{cases}$$

Phase Numerator- due to the ESR Zero of the output stage.

$\phi 1(f) := 57.3 \times \operatorname{atan}(2 \times \pi \times f \times ESR \times C)$

$\phi tot(f) := \phi 1(f) - \phi 1(f)$



$g_m := 0.99 \times 10^3 \times \Omega^{-1}$ MIC2169 transconductance gain.

$R1 := \dfrac{10^{\left|\frac{Mag}{20}\right|}}{g_m} \quad R1 = 2.034 \times 10^4 \Omega$

R1 is the compensation resistor.

$\theta_{lc} := 180 - 57.3\operatorname{atan}\left(\dfrac{f_c}{f_{esr}}\right) \quad \theta_{lc} = 109.472$

$\phi_m := 55$ Select required phase margin.

$P_{shift} := 360 - \phi_m$ $P_{shift} = 305$

$P_{errorpermitted} := P_{shift} - \theta_{lc}$ $P_{errorpermitted} = 195.528$ This number should be greater than 180 degrees.

$K_{fac} := \tan\left(\dfrac{360 - P_{errorpermitted}}{2} \times \dfrac{\pi}{180}\right) \quad K_{fac} = 7.335 \quad K := K_{fac}$

This value should be positive, otherwise cannot do this with a type II comp scheme.

$F_z := \frac{f_c}{K}$ $F_z = 6.817 \times 10^3 Hz$

Zero location.

$C1 := \frac{1}{2 \times \pi F_z \times R1}$ $C1 = 1.148 \times 10^{-9} F$

C1 is the compensation capacitor.

R1 in series with C1 and C2 is connected to GND on the comp pin.

$F_p := f_c \times K$ $F_p = 3.667 \times 10^5$ Hz

Pole location.

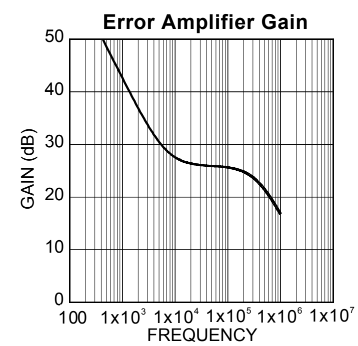
$C2 := \frac{1}{2 \times \pi F_p \times R1}$ $C2 = 2.134 \times 10^{-11} F$

C2 is capacitor in parallel with R1 in series with C1.

Error amplifier transfer function

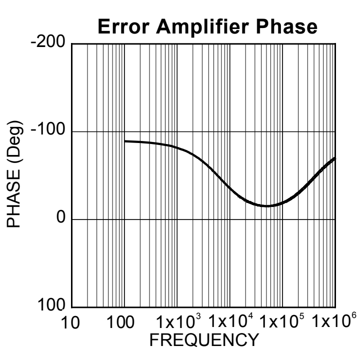
$$E(z) := g_m \times \left[\frac{1 + R1 \times S \times C1}{s \times (C1 + C2) \times \left(1 + R1 \times \frac{C1 \times C2 \times S}{C1 + C2}\right)} \right]$$

$$Error(f) := \left[20 \times \log\left(\frac{g_m}{C1 + C2}\right) + 20 \times \log\left[\sqrt{1 + (2 \times \pi \times f \times R1 \times C1)^2}\right] - 20 \times \log\left[\sqrt{1 + \left(\frac{2 \times \pi \times f \times R1 \times C1 \times C2}{C1 + C2}\right)^2}\right] - \left[20 \times \log\left[\sqrt{(2 \times \pi \times f)^2}\right]\right]\right]$$



$$ErPhase(f) := 57.3 \times \left(atan(2 \times \pi \times f \times R1 \times C1) - atan\left(\frac{2 \times \pi \times f \times R1 \times C1 \times C2}{C1 + C2}\right) - atan(2 \times \pi \times f) \right)$$

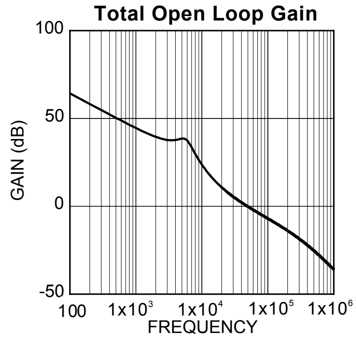
$$ErPhase1(f) := ErPhase(f) - 180$$

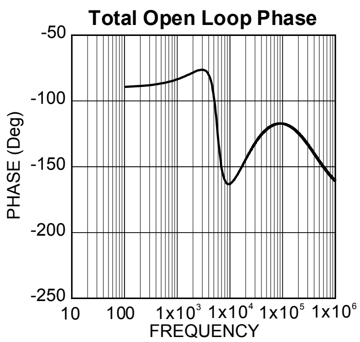


Total open loop

Cl(f) := G(f) + Error(f)

Clphase(f) := ErPhase1(f) ϕtot(f)





R1 = $2.034 \times 10^4 \Omega$

C1 = 1.148×10^{-9}F

C2 = 2.134×10^{-11}F

Compensation values.

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