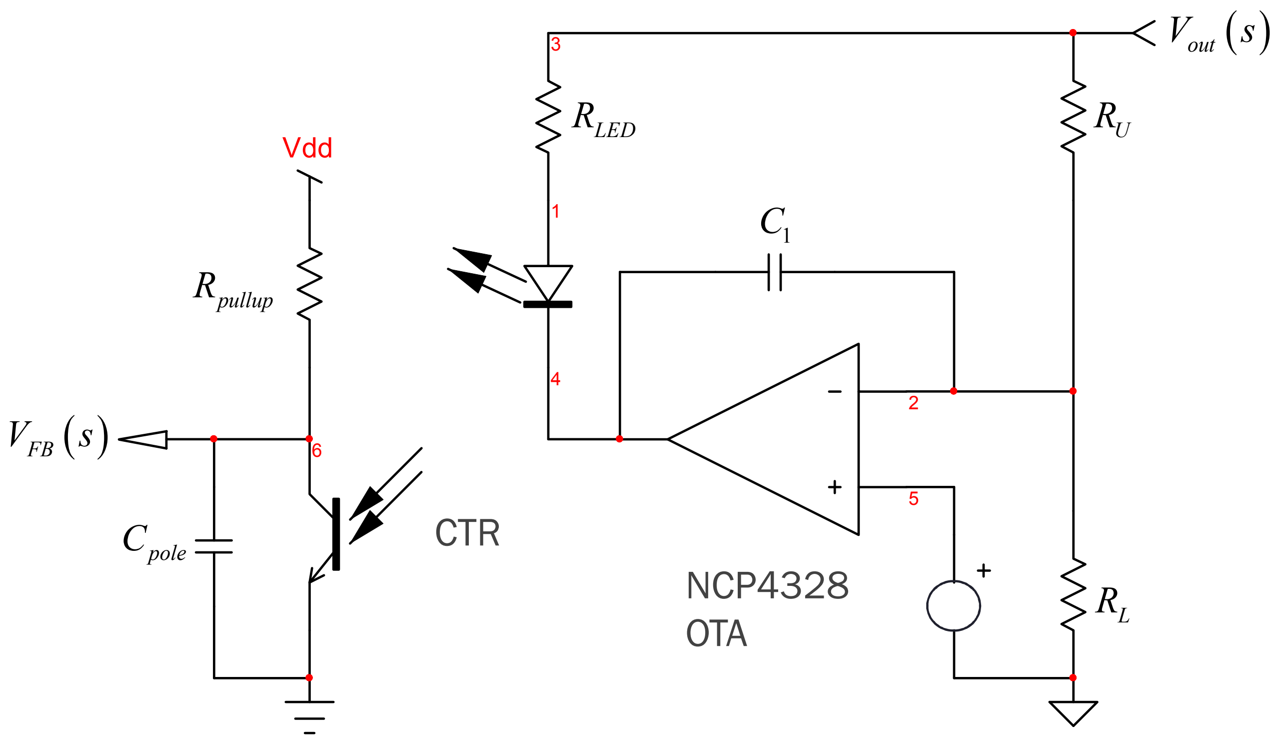
A Type 2 with NCP4352/28

Christophe Basso – Technical Fellow
IEEE Senior Member

ON Semiconductor®

Application Schematic



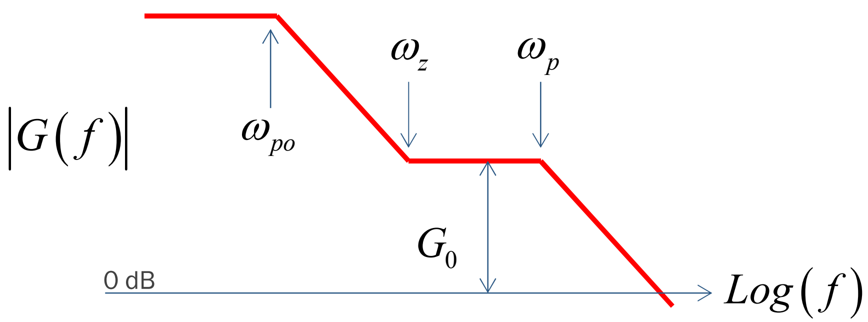
For this type 2 compensator (1 pole at the origin, 1 zero and 1 pole), a single capacitor C_1 is necessary. The second capacitor C_{pole} creates the needed pole for rolling off the gain at high frequencies.

$$G(s) = \frac{V_{FB}(s)}{V_{out}(s)}$$

Transfer Function

$$G(s) = -G_0 \frac{1+\frac{\omega_z}{s}}{1+\frac{\omega_{po}}{s}} \frac{1}{1+\frac{s}{\omega_p}} \qquad G_0 = \frac{\mathrm{CTR}\cdot R_{pullup}\left(R_U + R_L R_U g_m\right)}{\left(R_L + R_U + R_L R_U g_m\right) R_{LED} + R_L R_U} \qquad \omega_z = \frac{1}{C_1\left(\frac{R_U + R_L R_U g_m}{R_L g_m}\right)}$$

$$\omega_p = \frac{1}{C_{pole} R_{pullup}} \qquad \omega_{po} = \frac{1}{C_1\left[\frac{R_U\left(R_{LED} + R_L + R_L R_{LED} g_m\right) + R_L R_{LED}}{R_U + R_L}\right]}$$



1. Calculate R_{LED} to get G_0
2. Determine the value of C_1 for the zero
3. Determine the value of C_{pole} for the pole

The final value for C_{pole} must account for the optocoupler parasitic capacitance

Determining Components Values

$$R_U = \frac{V_{out} - V_{ref}}{i_{bias}} \qquad R_L = \frac{V_{ref}}{i_{bias}}$$

Bias current in the bridge

$$C_1 = \frac{R_L g_m}{2\pi f_z \left(R_U + R_L R_U g_m\right)}$$

$$R_{LED} = \frac{R_U \left(\mathrm{CTR} \cdot R_{pullup} - G_0 R_L + \mathrm{CTR} \cdot R_L R_{pullup} g_m\right)}{G_0 \left(R_L + R_U + R_L R_U g_m\right)}$$

Make sure the R_{LED} value is adequately selected to allow the proper optocoupler bias.

From IC specs → $g_m := 2S$ $\quad R_{pullup} := 20k\Omega$ $\quad CTR := 1$

Type 2 calculations:

$V_{out} := 12V \quad i_{bias} := 250\mu A \quad V_{ref} := 2.5V$

$R_L := \frac{V_{ref}}{i_{bias}} = 10 \cdot k\Omega \qquad R_U := \frac{V_{out} - V_{ref}}{i_{bias}} = 38 \cdot k\Omega$

Crossover and phase margin selection

Select crossover → $f_c := 1kHz$

Select phase margin → $pm := 70°$

$G_{fc} := -20 \quad pfc := -70°$

Data extracted from the plant control-to-output dynamic response:
G_{fc} is the gain/attenuation at f_c
pfc is the phase at f_c

$G_0 := 10^{-\frac{G_{fc}}{20}} = 10 \qquad boost := pm - (pfc) - 90° = 50 \cdot °$

$k := \tan\left(\frac{boost}{2} + 45°\right) = 2.747$

$f_z := \frac{f_c}{k} = 363.97Hz \qquad f_p := k \cdot f_c = 2.747kHz$

$C_{pole} := \frac{1}{2 \cdot \pi \cdot f_p \cdot R_{pullup}} = 2.896nF$

$C_1 := \frac{R_L \cdot g_m}{2 \cdot \pi \cdot f_z \cdot (R_U + R_L \cdot R_U \cdot g_m)} = 11.507nF$

$R_{LED} := \frac{R_U \cdot (CTR \cdot R_{pullup} - G_0 \cdot R_L + CTR \cdot R_L \cdot R_{pullup} \cdot g_m)}{G_0 \cdot (R_L + R_U + R_L \cdot R_U \cdot g_m)} = 1.999 \times 10^3 \Omega$

SPICE Simulation

parameters

Vout=12V
Ib=100u
Vref=2.5

Rupper=(Vout-Vref)/Ib
Rlower=2.5/Ib
Rpullup=20k
CTR = 1

fc=1k
pm=70
pfc=-70
Gfc=-20
boost=pm-(pfc)-90

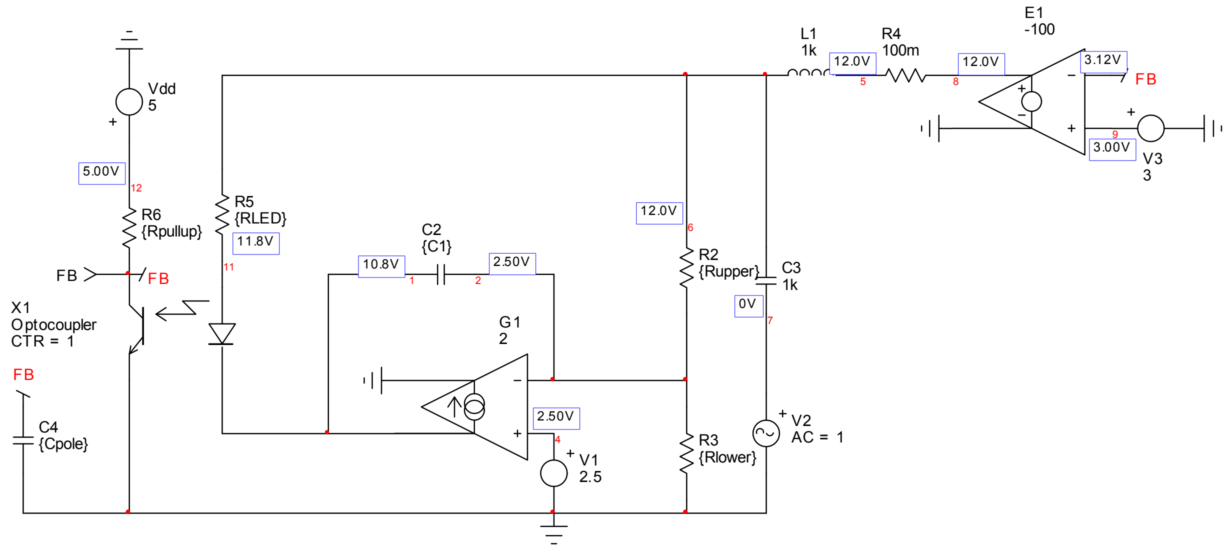
gm=2

G=10^(-Gfc/20)
pi=3.14159
K=tan((boost/2+45)*pi/180)

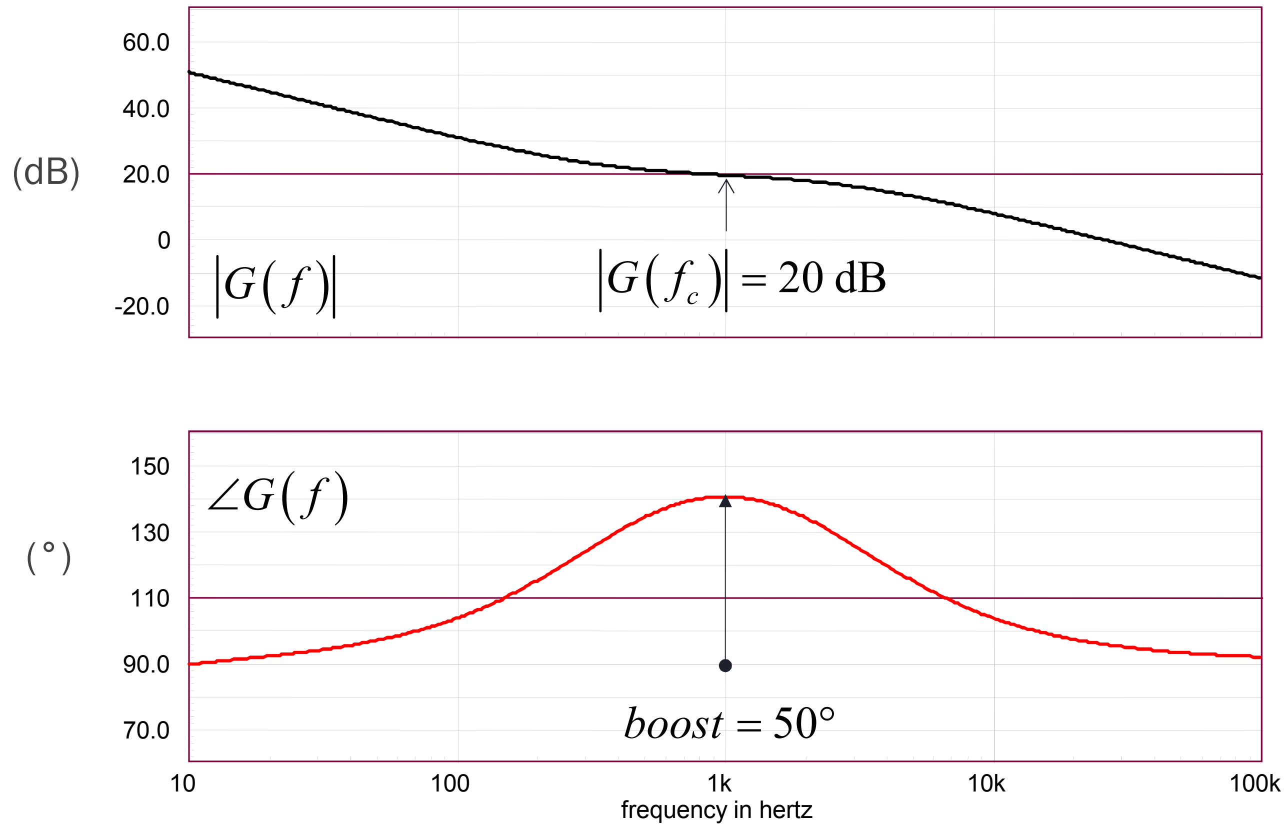
Fzero=fc/k
Fpole=k*fc

Cpole=1/(2*pi*Fpole*Rpullup)
C1=Rlower*gm/(2*pi*fzero*(Rupper+Rlower*Rupper*gm))

a=Rupper*(CTR*Rpullup-G*Rlower+CTR*Rlower*Rpullup*gm)
b=G*(Rupper+Rlower+Rlower*Rupper*gm)
RLED=a/b

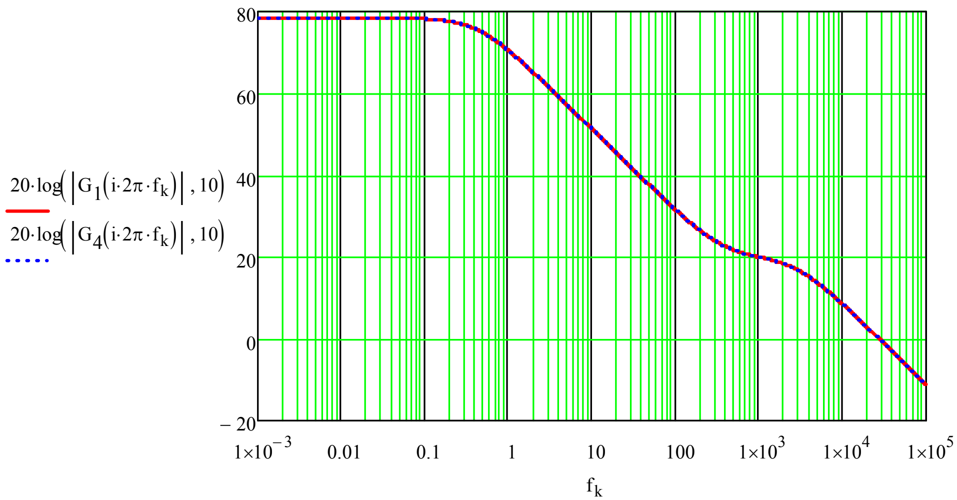


Small-Signal Response of the Compensator



Mathcad® Response

$\left|G(f)\right|$



$\angle G(f)$