Question 1(iii) and Question 2: AC small-signal Boost Converter

Define unit:

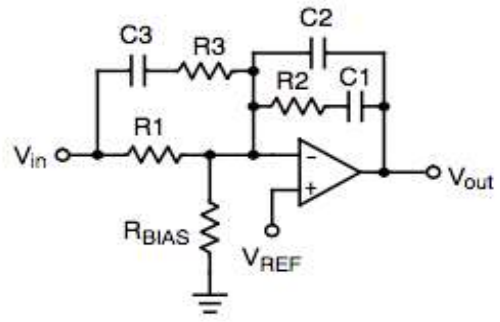
$\mu \equiv 10^{-6}$ $m \equiv 10^{-3}$ $V := 1$ $k\Omega \equiv 10^{3}$ $\Omega \equiv 1$ $H_z \equiv 1$ $nF \equiv 10^{-9}$ $pF \equiv 10^{-12}$ $nH \equiv 10^{-9}$

$dB \equiv 1$ $rad \equiv 1$ $kHz \equiv 10^{3}$ $\mu F \equiv 10^{-6}$ $\mu H \equiv 10^{-6}$

Boost Parameters:

$L := 25\mu H$ $C := 660\mu F$ $R_{ESR} := 50m$ $V_g := 20V$ $V_o := 30V$ $R := 15\Omega$

$f_s := 100kHz$ $V_m := 4V$ $V_{ref} := 3V$



Type 3 Error Amplifier

Question 1 (iii)

Pole-zero Locations and constants of the small-signal:

$D_{prim} := \frac{V_g}{V_o}$ $D_{prim} = 0.667$ $D := 1 - D_{prim}$ $D = 0.333$

$L_{eq} := \frac{L}{D_{prim}^{2}}$ $L_{eq} = 56.25\,\mu H$ $g_{od} := \frac{V_g}{D_{prim}^{2}}$ $g_{od} = 45$

$\omega_{zRHP} := \frac{R}{L_{eq}}$ $\omega_{zRHP} = 2.667 \times 10^{5}$ $f_{zRHP} := \frac{\omega_{zRHP}}{2\pi}$ $f_{zRHP} = 42.441\,kHz$

$\omega_{zESR} := \frac{1}{R_{ESR} \cdot C}$ $\omega_{zESR} = 3.03 \times 10^{4}$ $f_{zESR} := \frac{\omega_{zESR}}{2\pi}$ $f_{zESR} = 4.823\,kHz$

$\omega_o := \frac{1}{\sqrt{L_{eq} \cdot C}}$ $\omega_o = 5.19 \times 10^{3}$ $f_o := \frac{\omega_o}{2\pi}$ $f_o = 0.826\,kHz$

$$Q := R \cdot \sqrt{\frac{C}{L_{eq}}} \qquad Q = 51.381$$

Question 2 (i)

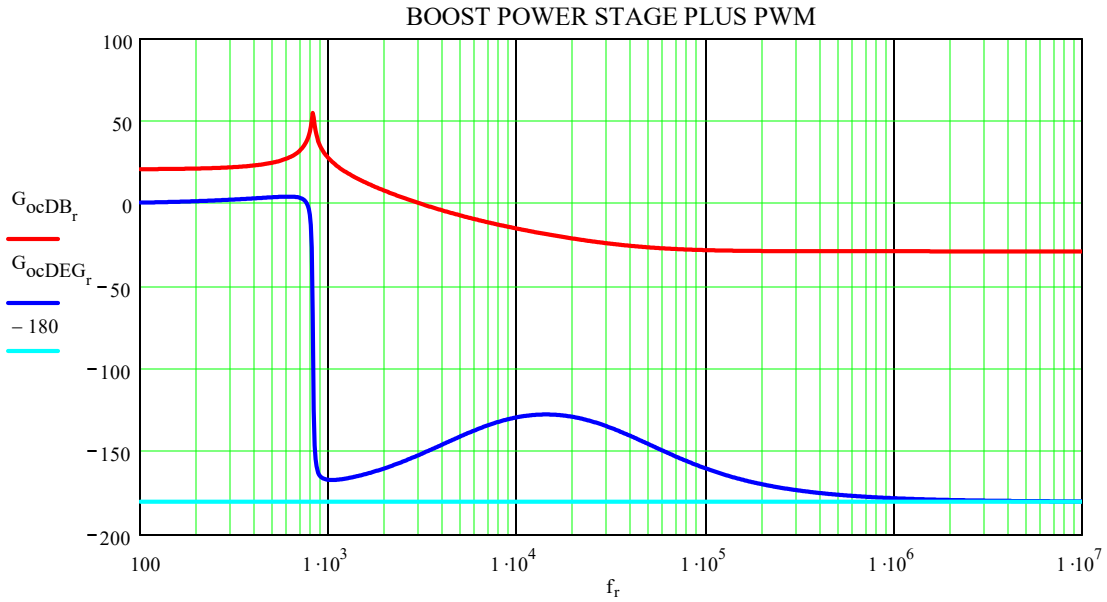
$$G_{oc}(s) := g_{od} \cdot \frac{\left(1 + \frac{s}{\omega_{zESR}}\right)\left(1 - \frac{s}{\omega_{zRHP}}\right)}{1 + \frac{s}{Q \cdot \omega_o} + \frac{s^2}{\omega_o{}^2}} \cdot \frac{1}{V_m}$$

Bode plot setting:

$N := 1000 \qquad r := 0 .. N - 1 \qquad f_{start} := 100 \qquad f_{stop} := 10000kHz \qquad f_r := f_{start} \cdot \left(\frac{f_{stop}}{f_{start}}\right)^{\frac{r}{N-1}}$

Define quantities for Bode plotting:

$$G_{ocDB_r} := 20 \cdot \log\left(\left|G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right|\right) \qquad G_{ocDEG_r} := \arg\left(G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right) \cdot \frac{180}{\pi}$$



Compensator Specifications:

$PM := 50deg \qquad f_{co} := 4kHz \qquad \omega_{co} := 2 \cdot \pi f_{co}$

$$GocdB := 20 \cdot \log\left(\left|G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_{co}\right)\right|\right) \qquad GocdB = -3.69$$

$$GocPh := \arg\left(G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_{co}\right)\right) \qquad GocPh = -145.472\ deg$$

Question 2 (ii)

$AcodB := GocdB$ $\quad Aco := 10^{\frac{AcodB}{20}}$ $\quad Aco = 0.654$ $\quad G := \frac{1}{Aco}$ $\quad G = 1.529$

$Pco := GocPh$ $\quad Pco = -145.472\,deg$

$Pboost := PM - Pco - 90deg$ $\quad Pboost = 105.472\,deg$

$f_o = 0.826\,kHz$ $\quad f_{z1} := f_o$ $\quad f_{z2} := f_o$ $\quad f_z := f_{z1}$ $\quad f_{p1} := f_{zRHP}$

$$PhFp2 := \operatorname{atan}\left(\frac{f_{co}}{f_{z1}}\right) + \operatorname{atan}\left(\frac{f_{co}}{f_{z2}}\right) - \operatorname{atan}\left(\frac{f_{co}}{f_{p1}}\right) - Pboost \qquad PhFp2 = 45.808\,deg$$

$$f_{p2} := \frac{f_{co}}{\tan(PhFp2)} \qquad f_{p2} = 3.889\,kHz$$

$$\omega_i := G \cdot 2 \cdot \pi \cdot f_{co} \cdot \frac{\sqrt{\left[1 + \left(\frac{f_{co}}{f_{p1}}\right)^2\right]} \cdot \sqrt{\left[1 + \left(\frac{f_{co}}{f_{p2}}\right)^2\right]}}{1 + \left(\frac{f_{co}}{f_z}\right)^2} \qquad \omega_i = 2.265 \times 10^3$$

Question 2 (iii)

$R1 := 4.7k\Omega$

$$C2 := \frac{1}{2\pi \cdot f_{co} \cdot G \cdot R1} \qquad C2 = 5.536 \times 10^3\,pF$$

$$C1 := C2 \cdot \left(\frac{f_{p2}}{f_{z1}} - 1\right) \qquad C1 = 20.526\,nF$$

$$R2 := \frac{1}{2 \cdot \pi \cdot f_{z1} \cdot C1} \qquad R2 = 9.387\,k\Omega$$

$$R3 := \frac{R1}{\left(\frac{f_{p1}}{f_{z2}} - 1\right)} \qquad R3 = 93.289$$

$$C3 := \frac{1}{\left(2\pi f_{p1} \cdot R3\right)} \qquad C3 = 40.198\,nF$$

To plot Loopgain and loop-phase

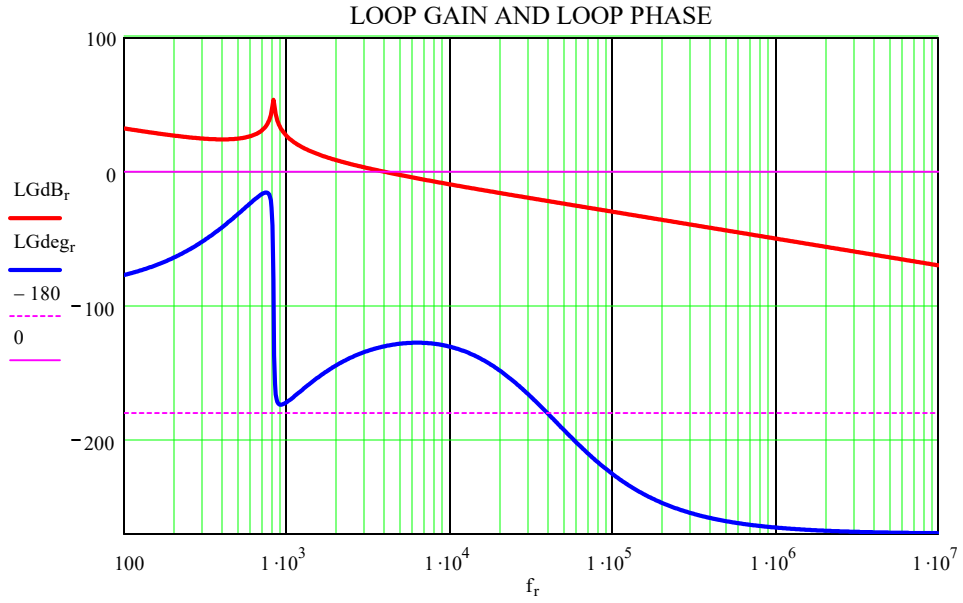
$$C(s) := \frac{\omega_i \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{z1}}\right) \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{z2}}\right)}{s \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{p1}}\right) \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{p2}}\right)}$$

$$LG(s) := g_{od} \cdot \frac{\left(1 + \frac{s}{\omega_{zESR}}\right) \cdot \left(1 - \frac{s}{\omega_{zRHP}}\right)}{1 + \frac{s}{Q \cdot \omega_o} + \frac{s^2}{{\omega_o}^2}} \cdot \frac{1}{V_m} \cdot \frac{\omega_i \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{z1}}\right) \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{z2}}\right)}{s \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{p1}}\right) \cdot \left(1 + \frac{s}{2 \cdot \pi \cdot f_{p2}}\right)}$$

Define quantities for Bode plot of Loop Gain LG:

$$LGdeg_r := \arg\left(G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right) \cdot \frac{180}{\pi} + \arg\left(C\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right) \cdot \frac{180}{\pi}$$

$$LGdB_r := 20 \cdot \log\left(\left|G_{oc}\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right|\right) + 20 \cdot \log\left(\left|C\left(j \cdot 2 \cdot \pi \cdot f_r\right)\right|\right)$$



Check:

$f_{co} = 4\ \text{kHz}$

$LGFco := \left|LG\left(j \cdot 2 \cdot \pi \cdot f_{co}\right)\right|$ $LGFco = 1$ 0 dB at fco **YES**

$LGdeg := \arg\left(LG\left(j \cdot 2 \cdot \pi \cdot f_{co}\right)\right)$ $LGdeg = -130\ \text{deg}$ PM = 50deg **YES**