OPO Compensation

Setup

```
Needs["Controls`LinearControl`"]

$TextStyle = {FontFamily → "Helvetica", FontSize → 13};

plotopt = PlotStyle → {{Thickness[0.007], RGBColor[1, 0, 0]},
               {Thickness[0.007], RGBColor[0, 0, 1]},
               {Thickness[0.007], RGBColor[0.1, 0.7, 0.2]},
               {Thickness[0.007], RGBColor[0.5, 0.5, 0.2]}};
```

par[r1_, r2_] := $\dfrac{1}{1/r1 + 1/r2}$

pole[f_, p_] := $\dfrac{1}{1 + i\, f/p}$

zero[f_, p_] := $1 + i\, f/p$

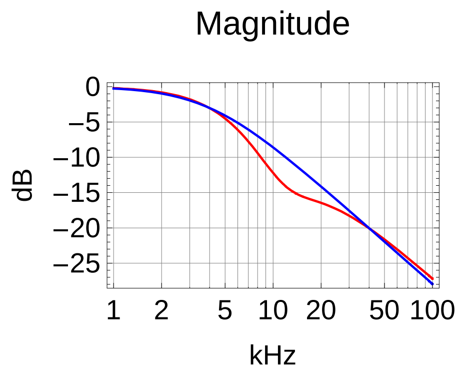
pole[f_, p_, Q_] := $\dfrac{1}{1 + i \frac{1}{Q} \frac{f}{p} - (f/p)^2}$

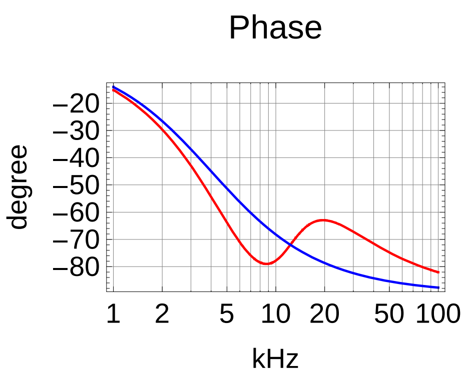
zero[f_, p_, Q_] := $1 + i \dfrac{1}{Q} \dfrac{f}{p} - (f/p)^2$

Target

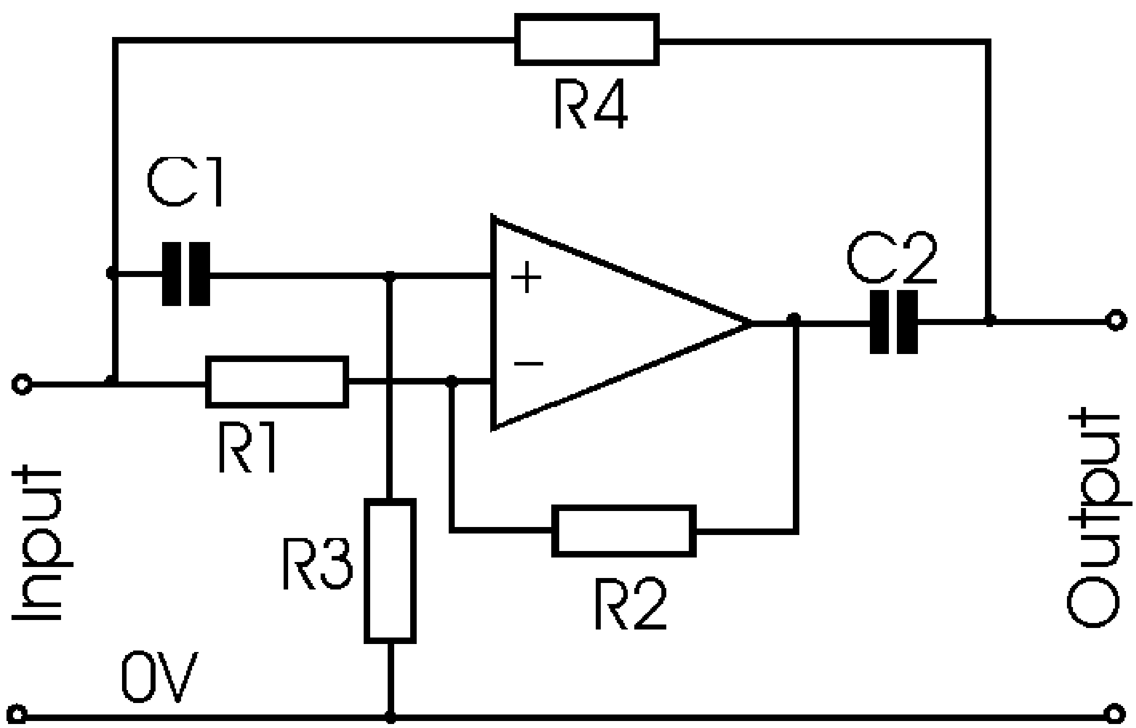
```
targ[f_] := zero[f, 12, 1] pole[f, 8]^2 pole[f, 10];
comp[f_] := pole[f, 4];
```

```
BodePlot[{targ[f], comp[f]}, {f, 1, 100}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```





Notch Circuit



Equations

C3 is at the output to ground.

$$eq1 = \frac{vp - vin}{\frac{1}{s\,C1}} + \frac{vp}{R3} == 0$$

$$eq2 = \frac{vm - vin}{R1} + \frac{vm - vo}{R2} == 0$$

$$eq3 = vm == vp$$

$$eq4 = R3 == R4$$

$$eq5 = C1 == C2$$

$$eq6 = \frac{vout - vo}{\frac{1}{s\,C2} + Rdamp} + \frac{vout - vin}{R4} + \frac{vout}{\frac{1}{s\,C3}} == 0$$

```
Solve[{eq1, eq2, eq3, eq4, eq5, eq6}, vout, {vp, vm, R4, C2, vo}]
```

$$sol = \frac{vout}{vin} \text{ /. } \%[[1]]$$

```
Limit[sol, s → 0]
```

$$\text{Collect}\left[\text{Simplify}\left[\frac{\text{Numerator}[sol]}{R1} \text{ /. } Rdamp \to 0 \text{ /. } R2 \to R1 - \frac{R1}{Q} \text{ /. } C1 \to \frac{1}{\omega\,R3}\right], s\right]$$

$$zsol = \text{Solve}\left[\frac{\text{Numerator}[sol]}{R1} == 0 \text{ /. } Rdamp \to 0 \text{ /. } R2 \to R1 - \frac{R1}{Q} \text{ /. } C1 \to \frac{1}{\omega\,R3}, s\right] \text{ // PowerExpand}$$

$$\text{Collect}\left[\text{Simplify}\left[\frac{\text{Denominator}[sol]}{R1} \text{ /. } Rdamp \to 0\right], s\right]$$

$$psol = \text{Solve}\left[\text{Denominator}[sol] == 0 \text{ /. } Rdamp \to 0 \text{ /. } R3 \to \frac{1}{\omega\,C1}, s\right]$$

$$\frac{vp}{R3} + C1\,s\,(-vin + vp) == 0$$

$$\frac{-vin + vm}{R1} + \frac{vm - vo}{R2} == 0$$

$$vm == vp$$

$$R3 == R4$$

$$C1 == C2$$

$$C3\,s\,vout + \frac{-vin + vout}{R4} + \frac{-vo + vout}{Rdamp + \frac{1}{C2\,s}} == 0$$

$$\{\{vout \to ((R1 + C1\,R1\,R3\,s - C1\,R2\,R3\,s + C1\,R1\,Rdamp\,s + C1^2\,R1\,R3^2\,s^2 + C1^2\,R1\,R3\,Rdamp\,s^2)\,vin) / (R1\,(1 + C1\,R3\,s)\,(1 + C1\,R3\,s + C3\,R3\,s + C1\,Rdamp\,s + C1\,C3\,R3\,Rdamp\,s^2))\}\}$$

$$(R1 + C1\,R1\,R3\,s - C1\,R2\,R3\,s + C1\,R1\,Rdamp\,s + C1^2\,R1\,R3^2\,s^2 + C1^2\,R1\,R3\,Rdamp\,s^2) / (R1\,(1 + C1\,R3\,s)\,(1 + C1\,R3\,s + C3\,R3\,s + C1\,Rdamp\,s + C1\,C3\,R3\,Rdamp\,s^2))$$

1

$$1+\frac{s^2}{\omega^2}+\frac{s}{Q\,\omega}$$

$$\left\{\left\{s\to\frac{-\omega-\sqrt{\omega^2-4\,Q^2\,\omega^2}}{2\,Q}\right\},\left\{s\to\frac{-\omega+\sqrt{\omega^2-4\,Q^2\,\omega^2}}{2\,Q}\right\}\right\}$$

$$1+(2\,C1\,R3+C3\,R3)\,s+\left(C1^2\,R3^2+C1\,C3\,R3^2\right)\,s^2$$

$$\left\{\{s\to-\omega\},\left\{s\to-\frac{C1\,\omega}{C1+C3}\right\}\right\}$$

Parameters

```
prm = {C1 → 3.3*^-9, R3 → 3.34*^3, R1 → 3.34*^3, R2 → 100, C3 → 4.7*^-9, Rdamp → 100}
```

$$\left\{C1\to3.3\times10^{-9},\ R3\to3340.,\ R1\to3340.,\ R2\to100,\ C3\to4.7\times10^{-9},\ Rdamp\to100\right\}$$

```
sol /. prm (* s polynominal *)
```

$\frac{1}{2\,\pi\,C1\,R3}$ `/. prm (* frequency of zeroes and one of the poles *)`

$\frac{R1}{R1-R2}$ `/. prm (* Q of zeroes *)`

$\frac{C1}{C1+C3}$ `/. prm (* shift of one of the poles *)`

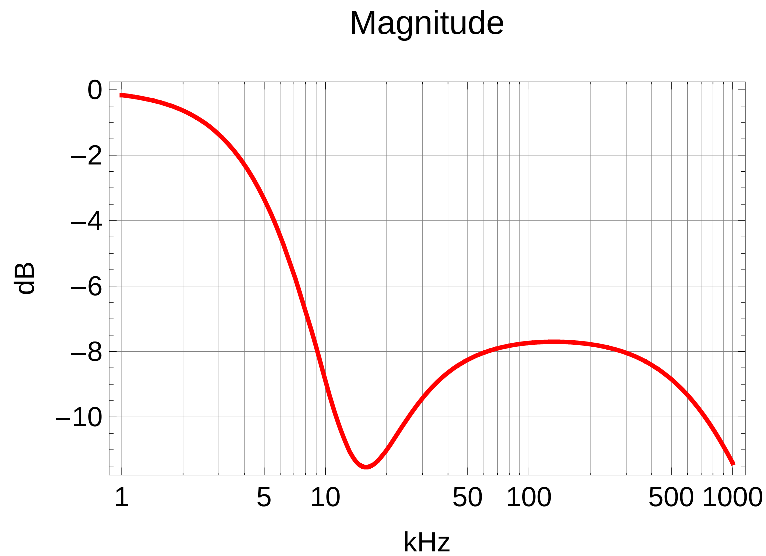
$$\frac{0.000299401\left(3340.+0.0368135\,s+4.17907\times10^{-7}\,s^2\right)}{(1+0.000011022\,s)\left(1+0.00002705\,s+5.18034\times10^{-12}\,s^2\right)}$$

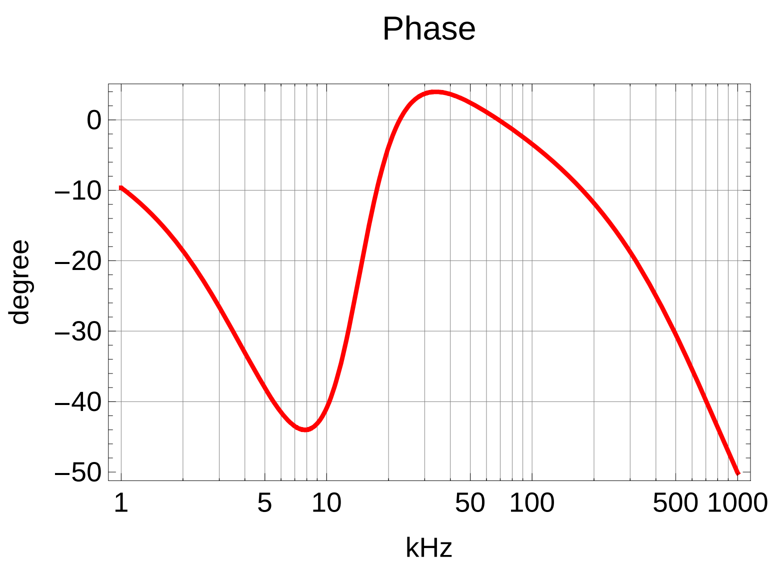
14439.8

1.03086

0.4125

```
BodePlot[sol /. prm /. s → 2 π ⅈ 1*^3 f, {f, 1, 1000},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```



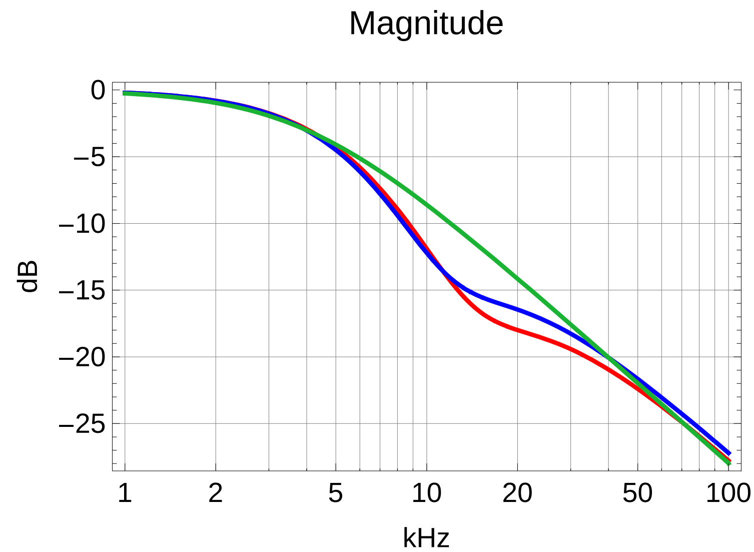


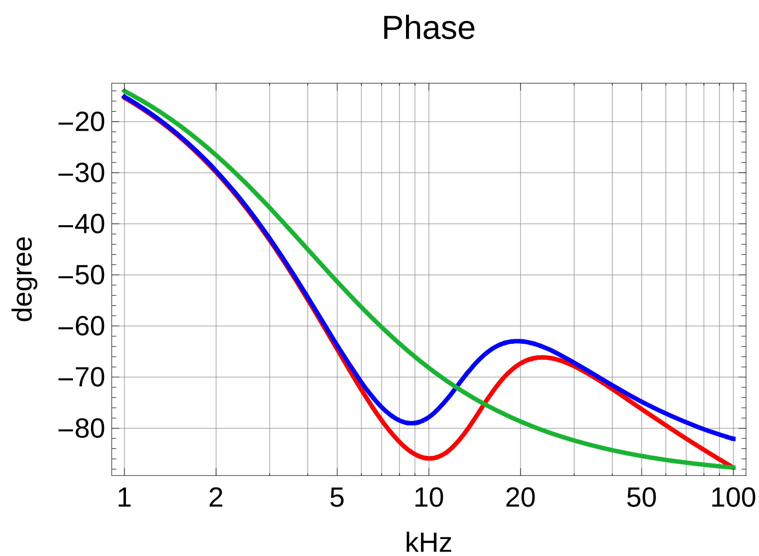
Damping

```
prm = {C1 → 3.3*^-9, R3 → 3.34*^3, R1 → 3.34*^3, R2 → 100, C3 → 4.7*^-9, Rdamp → 100}
```

$\{C1 \to 3.3 \times 10^{-9}, R3 \to 3340., R1 \to 3340., R2 \to 100, C3 \to 4.7 \times 10^{-9}, Rdamp \to 100\}$

```
BodePlot[{pole[f, 10] sol /. prm /. s → 2 π ⅈ 1*^3 f, targ[f], comp[f]},
  {f, 1, 100}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```






```
Solve[Numerator[sol] == 0 /. s → -2 π f, f] /. prm (* zero frequencies *)
√((f /. %[[1]]) (f /. %[[2]])) // Chop (* frequency *)
            1
―――――――――――――――――――――――――― (* Q *)
2 Sin[Arg[ⅈ f /. %%[[2]]]]
Solve[Denominator[sol /. Rdamp → 0] == 0 /. s → -2 π f, f] /. prm (* pole frequencies *)
```

```
{{f → 7010. - 12 381.6 ⅈ}, {f → 7010. + 12 381.6 ⅈ}}

14 228.3

1.01486

{{f → 14 439.8}, {f → 5956.4}}
```

```
BodePlot[{20 pole[f, 0.05] zero[f, 1] pole[f, 10] sol /. prm /. s → 2 π ⅈ 1*^3 f, targ[f], comp[f]},
 {f, .1, 100}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```