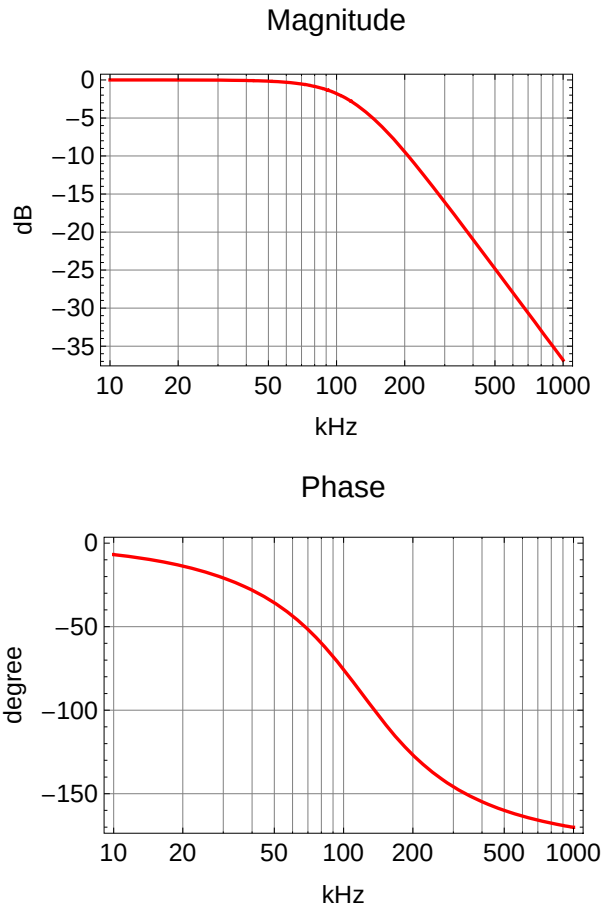
# SHG Compensation

## 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_] := 1 / (1/r1 + 1/r2)

pole[f_, p_] := 1 / (1 + i f/p)

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

pole[f_, p_, Q_] := 1 / (1 + i (1/Q) (f/p) - (f/p)^2)

zero[f_, p_, Q_] := 1 + i 1/Q f/p - (f/p)^2
```

# Target

```
tf = pole[f, 120, 0.7];
BodePlotEx[tf, {f, 10, 1000}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
Print ["Phase at 30kHz = ", Phase[tf /. f → 30] , "°"];
Print["Amplitude at 280kHz = ", dB[tf /. f → 280], " dB"];
```

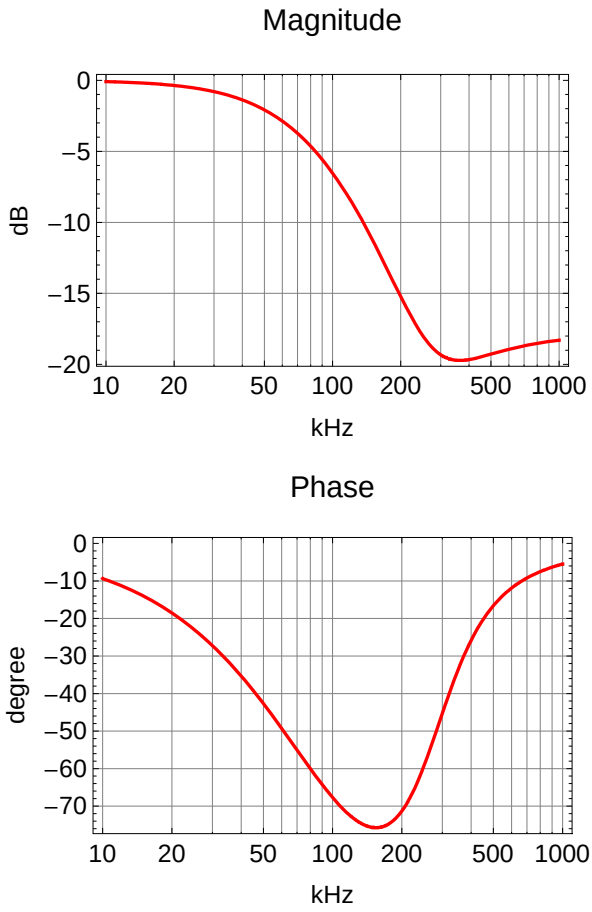




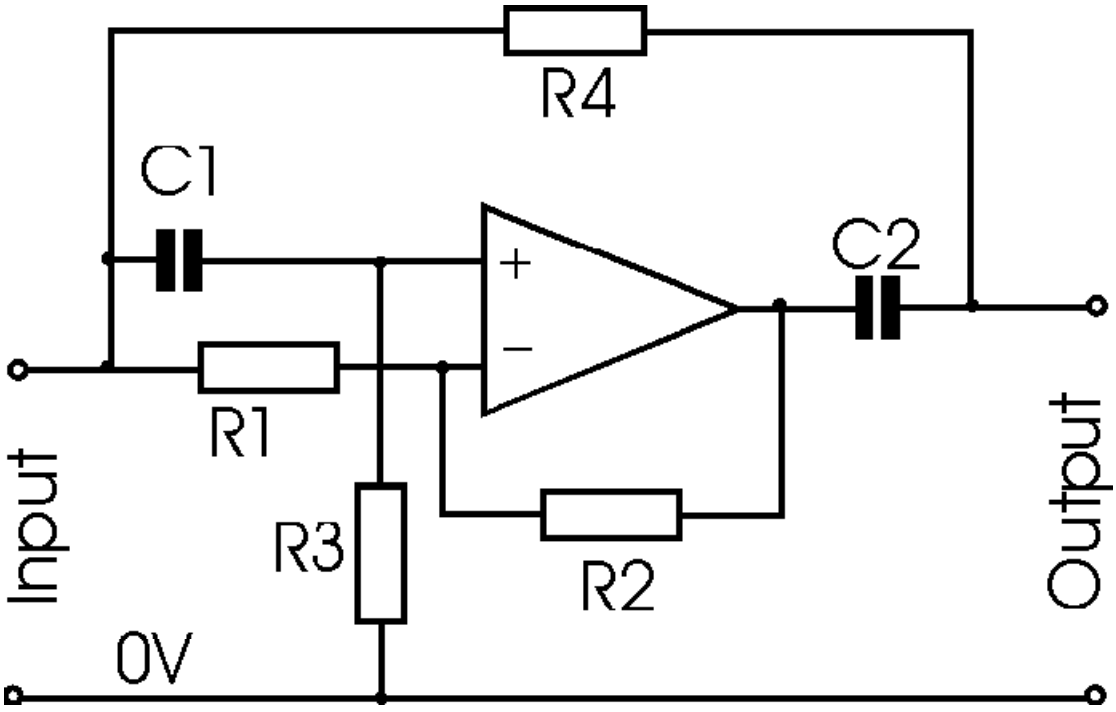


```
Phase at 30kHz = -20.8545°
Amplitude at 280kHz = -14.8945 dB
```

```
BodePlotEx[zero[f, 280, 1] pole[f, 100]^2, {f, 10, 1000},
  plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```



# Notch Circuit




## Equations

C3 is at the output to ground. Rdamp is in series with C2.

```
eq1 = (vp - vin)/(1/(s C1)) + vp/R3 == 0
eq2 = (vm - vin)/R1 + (vm - vo)/R2 == 0
eq3 = vm == vp
eq4 = R3 == R4
eq5 = C1 == C2
eq6 = (vout - vo)/(1/(s C2) + Rdamp) + (vout - vin)/R4 + vout/(1/(s C3)) == 0
Solve[{eq1, eq2, eq3, eq4, eq5, eq6}, vout, {vp, vm, R4, C2, vo}]
sol = Simplify[vout/vin /. %[[1]]]
Limit[sol, s → 0]
Collect[Simplify[Numerator[sol]/R1 /. Rdamp → 0 /. R2 → R1 - R1/Q /. C1 → 1/(ω R3)], s]
zsol = Solve[Numerator[sol]/R1 == 0 /. Rdamp → 0 /. R2 → R1 - R1/Q /. C1 → 1/(ω R3), s] // PowerExpand
Collect[Simplify[Denominator[sol]/R1 /. Rdamp → 0], s]
psol = Solve[Denominator[sol] == 0 /. Rdamp → 0 /. R3 → 1/(ω C1), s]
```

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

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

$$vm == vp$$

$$R3 == R4$$

$$C1 == C2$$

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

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

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

$$1$$

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

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

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

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

# Parameters

**prm = {C1 → 180.*^-12, R3 → 3.34*^3, R1 → 3.34*^3, R2 → 500., C3 → 330.*^-12, Rdamp → 0}**

$$\{C1 \to 1.8 \times 10^{-10},\ R3 \to 3340.,\ R1 \to 3340.,\ R2 \to 500.,\ C3 \to 3.3 \times 10^{-10},\ Rdamp \to 0\}$$

**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 *)**

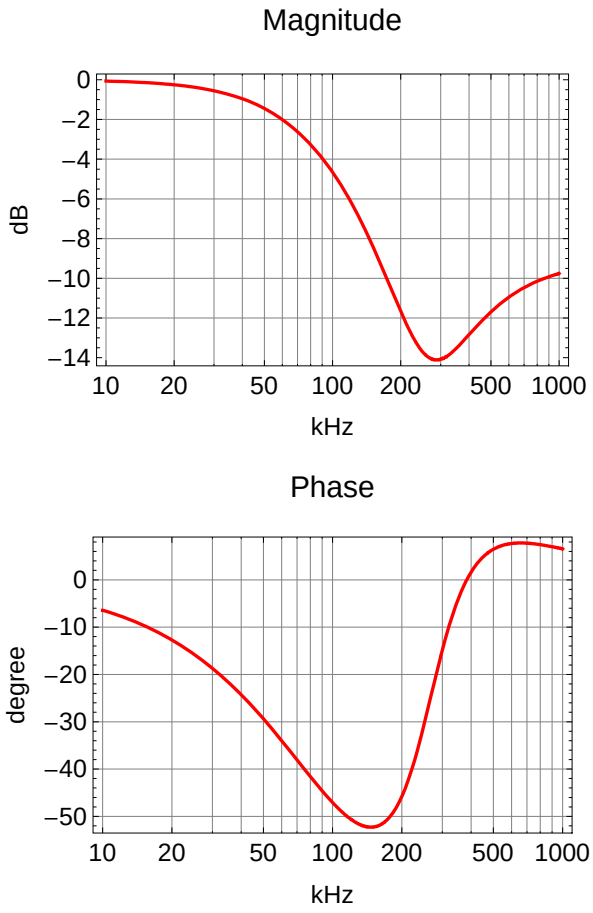
$$\left(0.000299401\left(-0.0003006\,s + 3340.\left(1 + 6.012 \times 10^{-7}\,s + 3.61441 \times 10^{-13}\,s^2\right)\right)\right) \Big/ \left(\left(1 + 6.012 \times 10^{-7}\,s\right)\left(1 + 1.7034 \times 10^{-6}\,s\right)\right)$$

264 729.

1.17606

0.352941

```
BodePlotEx[sol /. prm /. s → 2 π i 1*^3 f, {f, 10, 1000},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

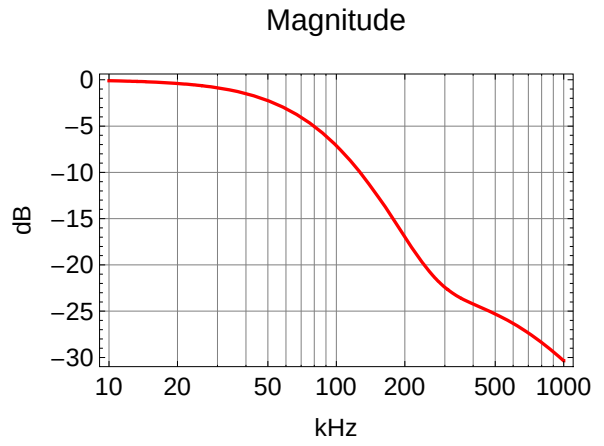


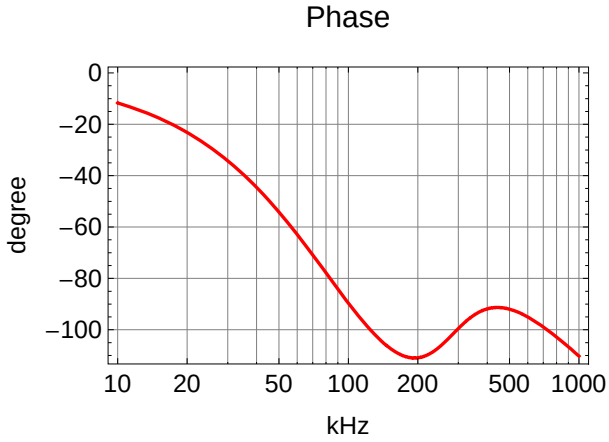

# Damping

```
prm = {C1 → 150.*^-12, R3 → 3.34*^3, R1 → 3.34*^3, R2 → 500., C3 → 330.*^-12, Rdamp → 1*^3}
```

$\{C1 \to 1.5 \times 10^{-10}, R3 \to 3340., R1 \to 3340., R2 \to 500., C3 \to 3.3 \times 10^{-10}, Rdamp \to 1000\}$

```
BodePlotEx[pole[f, 100] sol /. prm /. s → 2 π i 1*^3 f,
 {f, 10, 1000}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```




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

```
{{f → 140538. - 240652. i}, {f → 140538. + 240652. i}}
```

```
278683.
```

```
0.991487
```

```
{{f → 317675.}, {f → 96271.2}, {f → 1.59145 × 10^6}}
```