Squeezer Angle Compensation

Setup

In[1]:=
```
Needs["Controls`LinearControl`"]
```

In[2]:=
```
$TextStyle = {FontFamily → "Helvetica", FontSize → 13};
```

In[3]:=
```
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]}};
```

In[4]:=
$$\text{par}[r1\_, r2\_] := \frac{1}{1/r1 + 1/r2}$$

In[5]:=
$$\text{pole}[f\_, p\_] := \frac{1}{1 + i\, f/p}$$

$$\text{zero}[f\_, p\_] := 1 + i\, f/p$$

$$\text{pole}[f\_, p\_, Q\_] := \frac{1}{1 + i\,\frac{1}{Q}\,\frac{f}{p} - (f/p)^2}$$

$$\text{zero}[f\_, p\_, Q\_] := 1 + i\,\frac{1}{Q}\,\frac{f}{p} - (f/p)^2$$

Simplified Target

Target

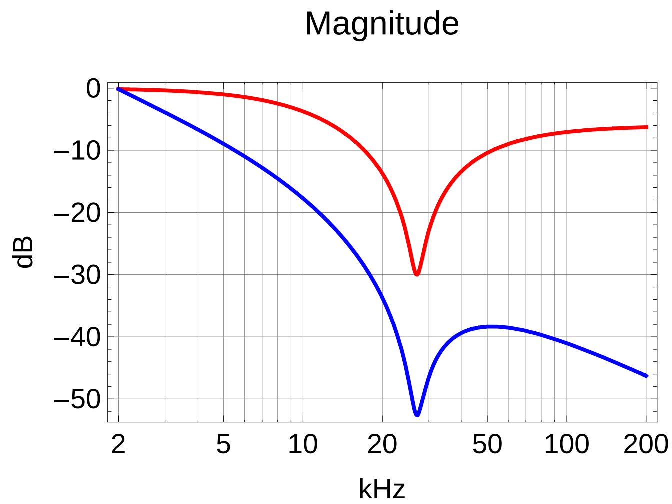
In[40]:=
$$\text{targ}[f\_] := \text{zero}[f, 25, 20]\ \text{pole}[f, 25]^2;$$
```
comp[f_] := zero[f, 10] pole[f, 40];
```

In[124]:=
```
targ[f_] := zero[f, 27, 10] pole[f, 27] pole[f, 13.5];
comp[f_] := 1000 pole[f, 0.002]
{targ[f], targ[f] comp[f]} /. f → 26.4 // dB
{targ[f], targ[f] comp[f]} /. f → 30. // dB
```

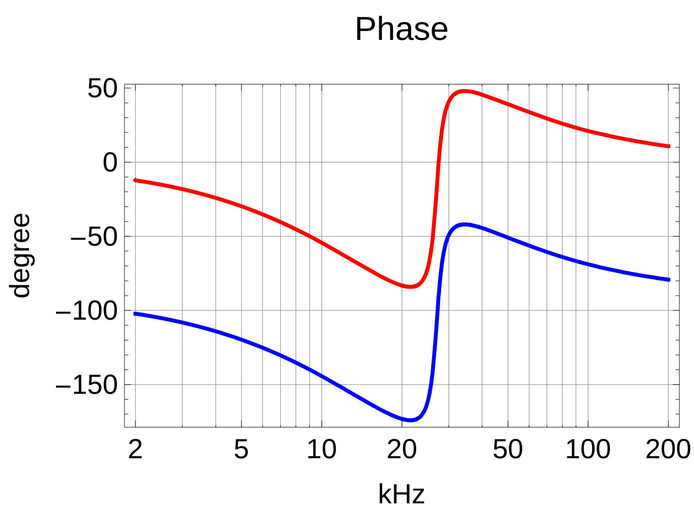
Out[126]= {-29.144, -51.5555}

Out[127]= {-22.944, -46.4658}

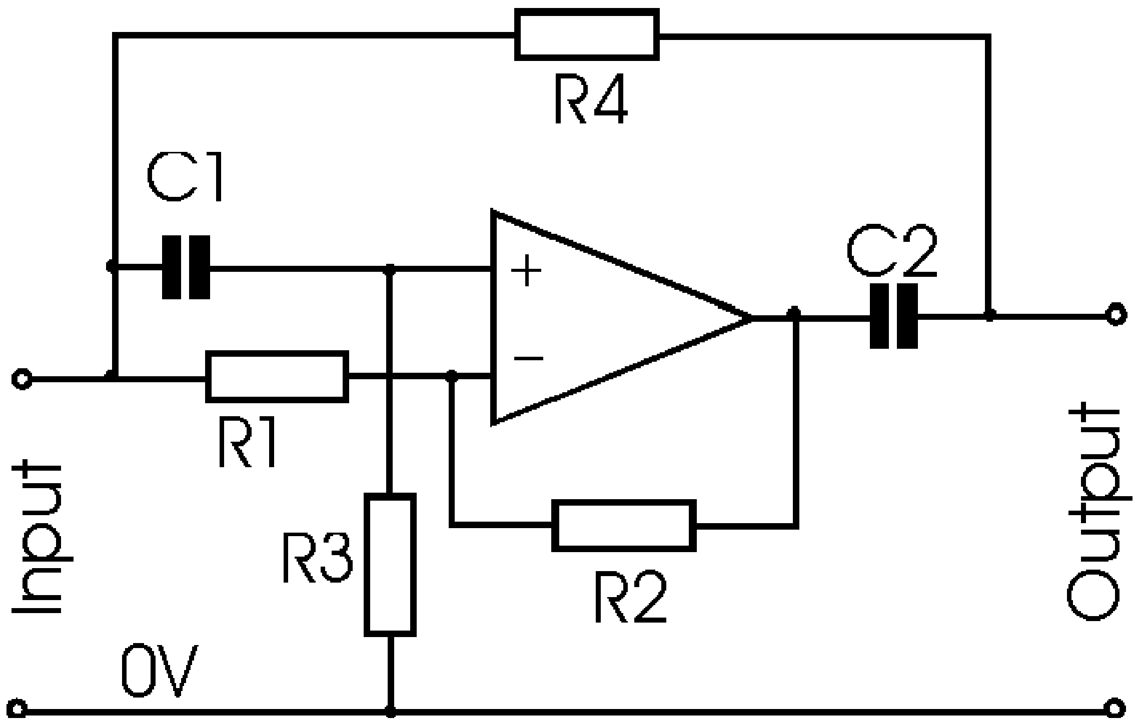
In[128]:=
```
BodePlot[{targ[f], targ[f] comp[f]}, {f, 2, 200}, plotopt,
  BaseStyle → $TextStyle, XAxisLabel → "kHz", MagnitudeRange → All]
```



Out[128]=



Notch Circuit



Equations

C3 is at the output to ground.

In[129]:=

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

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

```
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]
```

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

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

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

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

Out[129]= $\frac{vp}{R3} + C1\,s\,(-vin + vp) == 0$

Out[130]= $\frac{-vin + vm}{R1} + \frac{vm - vo}{R2} == 0$

Out[131]= $vm == vp$

Out[132]= $R3 == R4$

Out[133]= $C1 == C2$

Out[134]= $C3\,s\,vout + \frac{-vin + vout}{R4} + \frac{-vo + vout}{Rdamp + \frac{1}{C2\,s}} == 0$

Out[135]= $\{\{vout \to ((R1 + C1\,R1\,R3\,s - C1\,R2\,R3\,s + C1\,R1\,Rdamp\,s + C1^2\,R1\,R3^2\,s^2 + C1^2\,R1\,R3\,Rdamp\,s^2)\,vin) / (R1\,(1 + C1\,R3\,s)\,(1 + C1\,R3\,s + C3\,R3\,s + C1\,Rdamp\,s + C1\,C3\,R3\,Rdamp\,s^2))\}\}$

Out[136]= $(R1 + C1\,R1\,R3\,s - C1\,R2\,R3\,s + C1\,R1\,Rdamp\,s + C1^2\,R1\,R3^2\,s^2 + C1^2\,R1\,R3\,Rdamp\,s^2) / (R1\,(1 + C1\,R3\,s)\,(1 + C1\,R3\,s + C3\,R3\,s + C1\,Rdamp\,s + C1\,C3\,R3\,Rdamp\,s^2))$

Out[137]= 1

Out[138]= $1 + \frac{s^2}{\omega^2} + \frac{s}{Q\,\omega}$

Out[139]= $\left\{\left\{s \to \frac{-\omega - \sqrt{\omega^2 - 4\,Q^2\,\omega^2}}{2\,Q}\right\}, \left\{s \to \frac{-\omega + \sqrt{\omega^2 - 4\,Q^2\,\omega^2}}{2\,Q}\right\}\right\}$

Out[140]= $1 + (2\,C1\,R3 + C3\,R3)\,s + \left(C1^2\,R3^2 + C1\,C3\,R3^2\right)\,s^2$

Out[141]= $\left\{\{s \to -\omega\}, \left\{s \to -\frac{C1\,\omega}{C1 + C3}\right\}\right\}$

Parameters

In[241]:= **prm = {C1 → 1.8*^-9, R3 → 3.34*^3, R1 → 3.34*^3, R2 → 3.01*^3, C3 → 1.8*^-9, Rdamp → 20}**

Out[241]= $\left\{C1 \to 1.8 \times 10^{-9}, R3 \to 3340., R1 \to 3340., R2 \to 3010., C3 \to 1.8 \times 10^{-9}, Rdamp \to 20\right\}$

In[242]:= **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 *)**

Out[242]= $\frac{0.000299401\left(3340. + 0.0021042\,s + 1.21444 \times 10^{-7}\,s^2\right)}{\left(1 + 6.012 \times 10^{-6}\,s\right)\left(1 + 0.00001206\,s + 2.16432 \times 10^{-13}\,s^2\right)}$

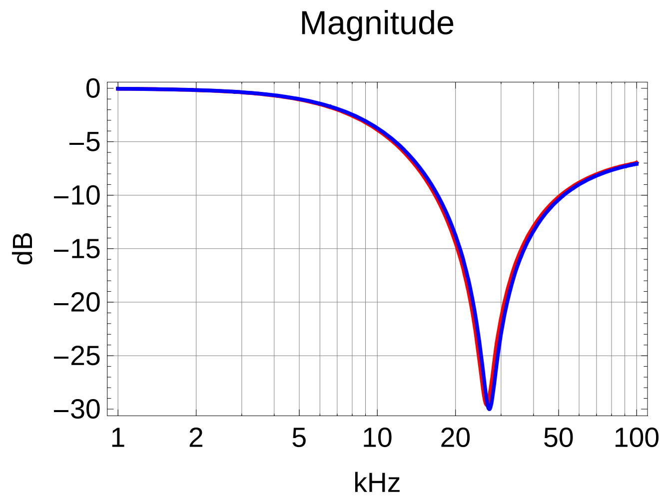
Out[243]= 26472.9

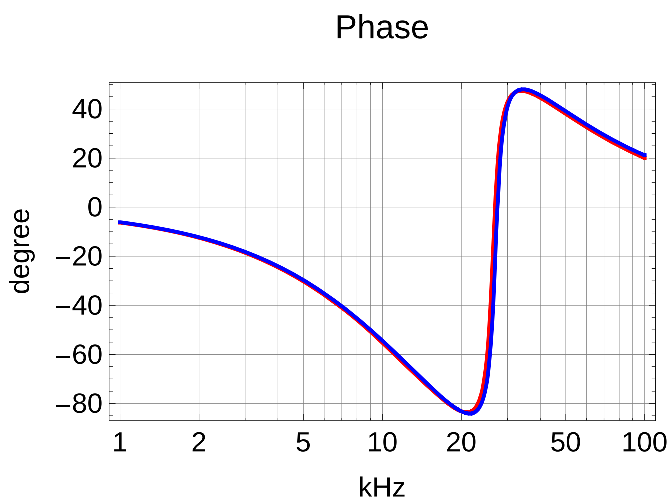
Out[244]= 10.1212

Out[245]= 0.5

In[246]:=
```
BodePlot[{sol /. prm /. s → 2 π ⅈ 1*^3 f, targ[f]}, {f, 1, 100},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz", MagnitudeRange → All]
```

Out[246]=





In[247]:=
```
Solve[Numerator[sol] == 0 /. s → -2 π f, f] /. prm (* zero frequencies *)
√((f /. %[[1]]) (f /. %[[2]])) // Chop (* frequency *)
1/(2 Sin[Arg[ⅈ f /. %%[[2]]]]) (* Q *)
Solve[Denominator[sol /. Rdamp → 0] == 0 /. s → -2 π f, f] /. prm (* pole frequencies *)
```

Out[247]= {{f → 1378.8 − 26 357.9 ⅈ}, {f → 1378.8 + 26 357.9 ⅈ}}

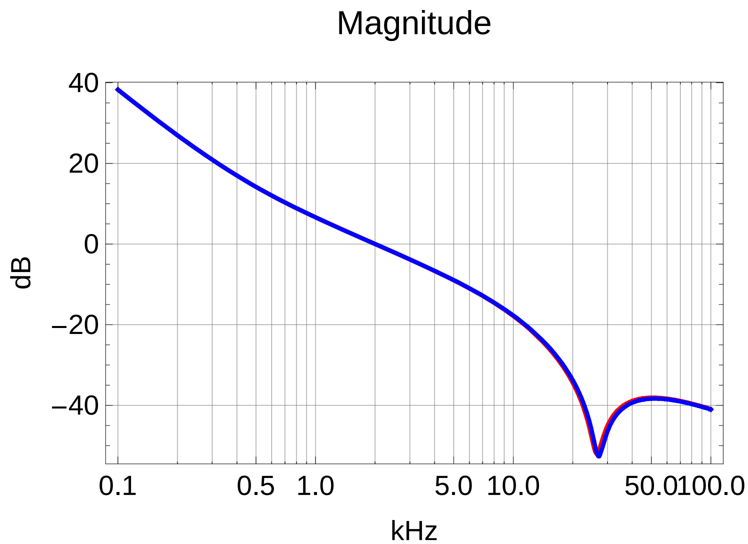
Out[248]= 26 394.

Out[249]= 9.57139

Out[250]= {{f → 26 472.9}, {f → 13 236.4}}

Compensation

In[251]:=
```
boost[f_] := 100 pole[f, 0.004] zero[f, 0.4]
BodePlot[
 {200 pole[f, 0.01] boost[f] sol /. prm /. s → 2 π ⅈ 1*^3 f, 200 pole[f, 0.01] boost[f] targ[f]},
 {f, .1, 100}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```



Out[252]=