Squeezer

SHG/OPO Notch

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]}};
```

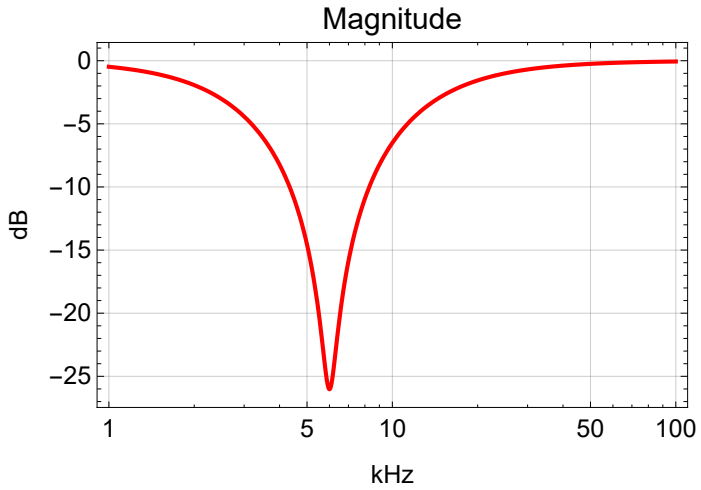
In[4]:=
```
par[r1_, r2_] := 1 / (1/r1 + 1/r2)
```

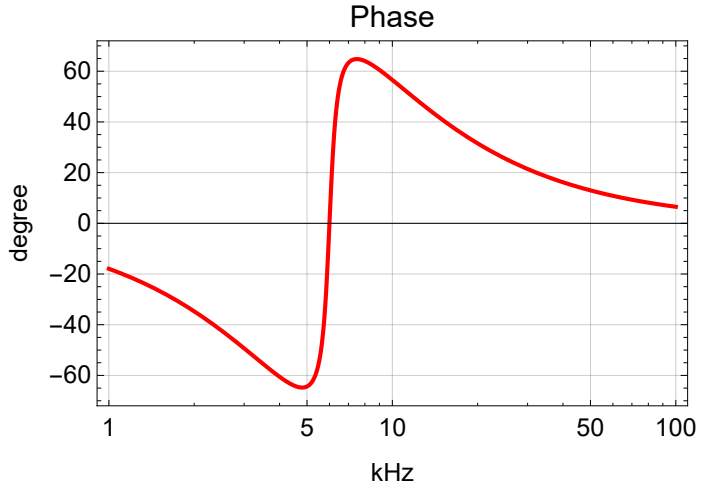
In[5]:=
```
pole[f_, p_] := 1 / (1 + i f/p)
zero[f_, p_] := 1 + i f/p
pole[f_, p_, Q_] := 1 / (1 + i 1/Q f/p - (f/p)^2)
zero[f_, p_, Q_] := 1 + i 1/Q f/p - (f/p)^2
```

Target

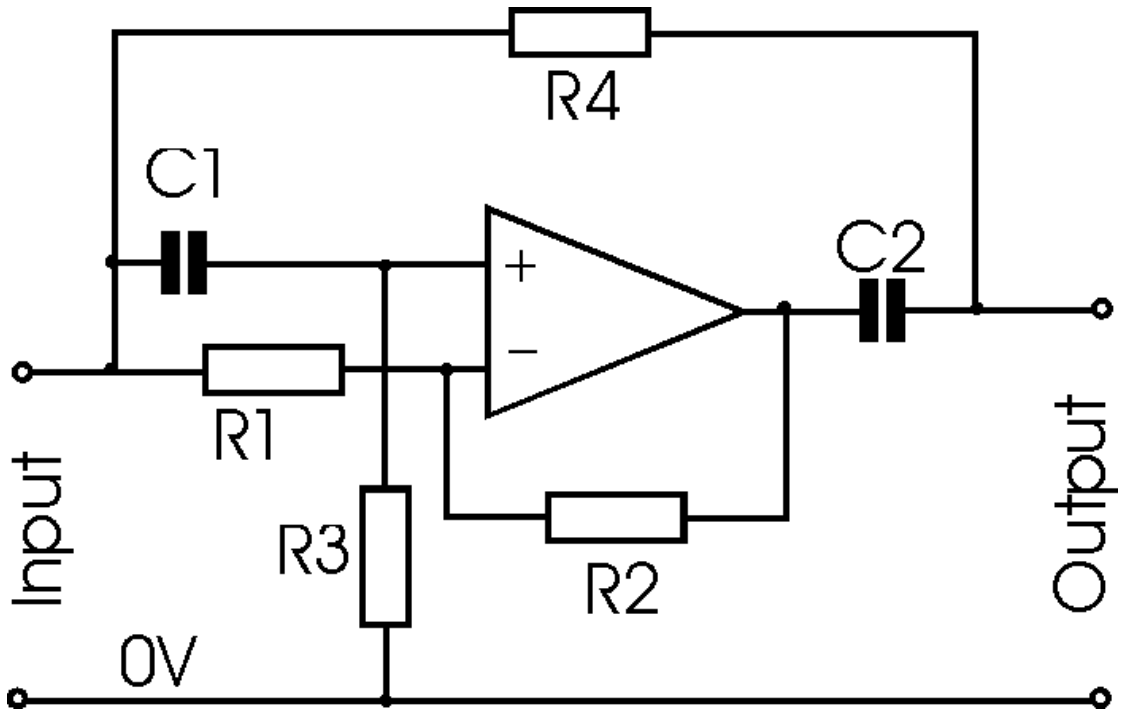
In[156]:=
```
BodePlotEx[zero[f, 6, 10] pole[f, 6]^2, {f, 1, 100},
  plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[156]=





Notch Circuit



Equations

C3 is at the output to ground.

Rdamp is in series with C2.

In[18]:=
```
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]
```

Out[18]=
$$\frac{vp}{R3} + C1\, s\, (-vin + vp) == 0$$

Out[19]=
$$\frac{-vin + vm}{R1} + \frac{vm - vo}{R2} == 0$$

Out[20]=
$$vm == vp$$

Out[21]=
$$R3 == R4$$

Out[22]=
$$C1 == C2$$

Out[23]=
$$C3\, s\, vout + \frac{-vin + vout}{R4} + \frac{-vo + vout}{Rdamp + \frac{1}{C2\, s}} == 0$$

Out[24]=
$$\left\{\left\{vout \to \left(R1\, vin + C1\, R1\, R3\, s\, vin - C1\, R2\, R3\, s\, vin + C1\, R1\, Rdamp\, s\, vin + C1^2\, R1\, R3^2\, s^2\, vin + C1^2\, R1\, R3\, Rdamp\, s^2\, vin\right) \Big/ \left(R1\, (1 + C1\, R3\, s)\, (1 + C1\, R3\, s + C3\, R3\, s + C1\, Rdamp\, s + C1\, C3\, R3\, Rdamp\, s^2)\right)\right\}\right\}$$

Out[25]=
$$\left(R1 - C1\, R2\, R3\, s + C1\, R1\, (R3 + Rdamp)\, s + C1^2\, R1\, R3\, (R3 + Rdamp)\, s^2\right) \Big/ \left(R1\, (1 + C1\, R3\, s)\, (1 + C3\, R3\, s + C1\, s\, (R3 + Rdamp + C3\, R3\, Rdamp\, s))\right)$$

Out[26]=
$$1$$

Out[27]=
$$1 + \frac{s^2}{\omega^2} + \frac{s}{Q\, \omega}$$

Out[28]=
$$\left\{\left\{s \to \frac{-\omega - \sqrt{\omega^2 - 4\, Q^2\, \omega^2}}{2\, Q}\right\}, \left\{s \to \frac{-\omega + \sqrt{\omega^2 - 4\, Q^2\, \omega^2}}{2\, Q}\right\}\right\}$$

Out[29]= $1 + \left(2\,C1\,R3 + C3\,R3\right)\,s + \left(C1^2\,R3^2 + C1\,C3\,R3^2\right)\,s^2$

Out[30]= $\left\{\{s \to -\omega\},\ \left\{s \to -\frac{C1\,\omega}{C1 + C3}\right\}\right\}$

Parameters

In[407]:=
```
prm = {C1 → 10*^-9, R3 → 2.4*^3, R1 → 2.4*^3, R2 → 2.32*^3, C3 → 1.0*^-9, Rdamp → 0}
```

Out[407]= $\left\{C1 \to \frac{1}{100\,000\,000},\ R3 \to 2400.,\ R1 \to 2400.,\ R2 \to 2320.,\ C3 \to 1. \times 10^{-9},\ Rdamp \to 0\right\}$

In[408]:=
```
sol /. prm (* s polynominal *)
1/(2 π C1 R3) /. prm (* frequency of zeroes and one of the poles *)
R1/(R1 - R2) /. prm (* Q of zeroes *)
C1/(C1 + C3) /. prm (* shift of one of the poles *)
```

Out[408]= $\left(0.000416667\,\left(2400. + 0.00192\,s + 1.3824 \times 10^{-6}\,s^2\right)\right) \Big/ \left(\left(1 + 0.000024\,s\right)\,\left(1 + 0.0000264\,s\right)\right)$

Out[409]= 6631.46

Out[410]= 30.

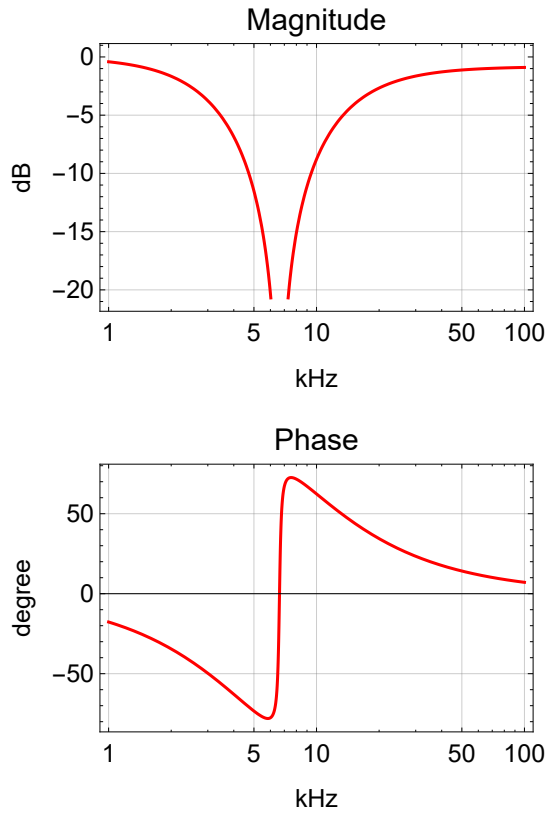
Out[411]= 0.909091

In[412]:=
```
{dB[#], Phase[#]} &[sol] /. prm /. s → 2 π i 1*^3 f /. f → 2
```

Out[412]= {-1.65934, -34.5027}

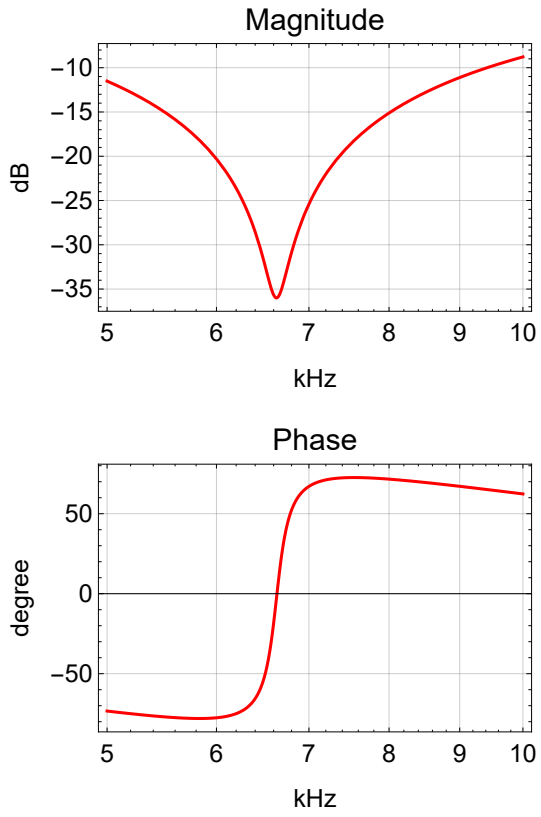
In[415]:=
```
BodePlotEx[sol /. prm /. s → 2 π ⅈ 1*^3 f, {f, 1, 100},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[415]=



In[414]:=
```
BodePlotEx[sol /. prm /. s → 2 π i 1*^3 f, {f, 5, 10},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[414]=



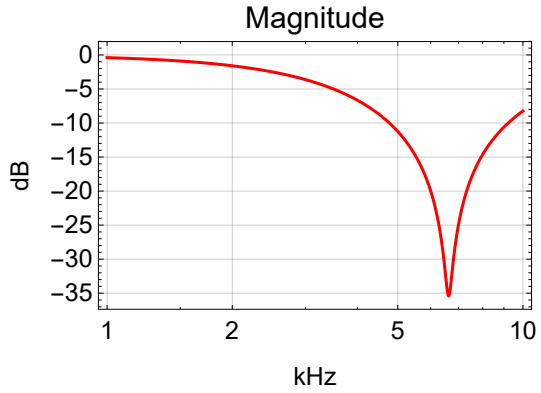
Damping

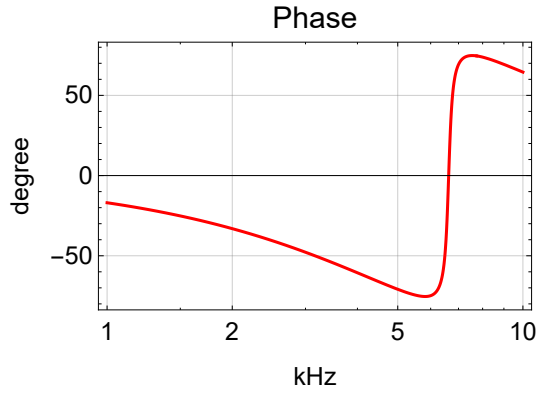
In[416]:=
```
prm = {C1 → 10*^-9, R3 → 2.4*^3, R1 → 2.4*^3, R2 → 2.32*^3, C3 → 0.1*^-9, Rdamp → 2}
```

Out[416]= $\left\{C1 \to \frac{1}{100\,000\,000}, R3 \to 2400., R1 \to 2400., R2 \to 2320., C3 \to 1. \times 10^{-10}, Rdamp \to 2\right\}$

In[417]:=
```
BodePlotEx[sol /. prm /. s → 2 π i 1*^3 f, {f, 1, 10},
 plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[417]=





In[418]:=
```
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] == 0 /. s → -2 π f, f] /. prm (* pole frequencies *)
```

Out[418]= $\{\{f \to 113.193 - 6627.73\, i\}, \{f \to 113.193 + 6627.73\, i\}\}$

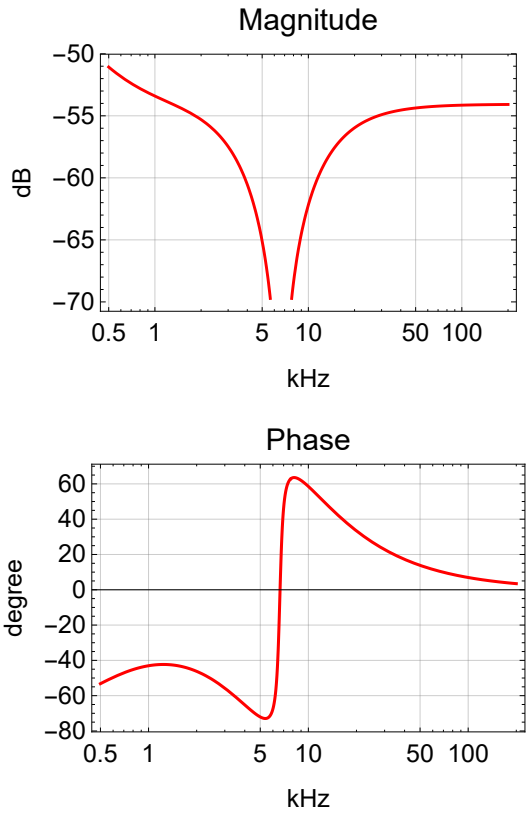
Out[419]= 6628.69

Out[420]= 29.2805

Out[421]= $\left\{\{f \to 6631.46\}, \{f \to 6560.44\}, \left\{f \to 8.04389 \times 10^{8}\right\}\right\}$

In[239]:=
```
BodePlotEx[pole[f, 0.001] zero[f, 2] zero[f, 0.5] pole[f, 2] sol /. prm /. s → 2 π i 1*^3 f,
 {f, 0.5, 200}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[239]=




```
1 + R6 / (1/(s CC) + R7) // Together
Solve[Numerator[% /. s → -2 π f] == 0, f]
Solve[Denominator[%% /. s → -2 π f] == 0, f]
```

Out[150]= $\frac{1 + CC\ R6\ s + CC\ R7\ s}{1 + CC\ R7\ s}$

Out[151]= $\left\{\left\{f \to \frac{1}{2\ CC\ \pi\ (R6 + R7)}\right\}\right\}$

Out[152]= $\left\{\left\{f \to \frac{1}{2\ CC\ \pi\ R7}\right\}\right\}$

Boost

In[337]:=
```
prm2 = {R2 → 2.4*^3, R1 → 806, C → 1*^-6}
```

Out[337]= $\left\{R2 \to 2400.,\ R1 \to 806,\ C \to \frac{1}{1\,000\,000}\right\}$

In[338]:=
```
boost = 1 + par[R2, 1/(s C)] // Together
Solve[Numerator[boost] == 0, s][[1]]
-s/(2 π) /. % /. prm2
Solve[Denominator[boost] == 0, s][[1]]
-s/(2 π) /. % /. prm2
```

Out[338]=
$$\frac{R1 + R2 + C\ R1\ R2\ s}{R1\ (1 + C\ R2\ s)}$$

Out[339]=
$$\left\{s \to \frac{-R1 - R2}{C\ R1\ R2}\right\}$$

Out[340]= 263.777

Out[341]=
$$\left\{s \to -\frac{1}{C\ R2}\right\}$$

Out[342]= 66.3146

In[422]:=
```
BodePlotEx[(boost /. prm2) (sol /. prm) /. s → 2 π i 1*^3 f,
 {f, .01, 100}, plotopt, BaseStyle → $TextStyle, XAxisLabel → "kHz"]
```

Out[422]=