Sinteza električnih filtara

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SC filtri (integrisana kola)

- Nema slabljenja u propusnom opsegu
- Moguća pojačanja u propusnom opsegu
- Realizacija svih vrsta filtara sa jednim univerzalnim IC
- Nema L
- Nema C (da se dodaju spolja)
- Minimalan broj R
- Ulazna impedansa je velika
- Izlazna impedansa je mala
- Male dimenzije i težina
- Jednostavno podešavanje
- Rad na niskim učestanostima (oko 0.1 Hz)
- Jednostavan postupak sinteze
- Kratko vreme projektovanja

SC filtri - nedostaci

- Aktivne komponente generišu šum
- Ograničen dinamički opseg na oko 80 dB
- Gornja granica rada do 200 kHz
- Pojava komponenti visokih učestanosti (od takta na kome radi)
- Potrebno eksterno napajanje
- Potreban eksterni klok signal (u nekim slučajevima)

SC filtri – princip rada

- R se simulira sa C i prekidačima
- Otpornost otpornika se definiše kao količnik napona na R i struje kroz R
- Kada se na C dovodi napon V_s sa taktom f_{CLK}, srednja struje je proporcionalna sa $q=CV_s$

$$I_{average} = V_s C f_{CLK}$$

$$R = \frac{V_s}{I_{average}} = \frac{1}{C f_{CLK}}$$

Tolerancije - osetljivost

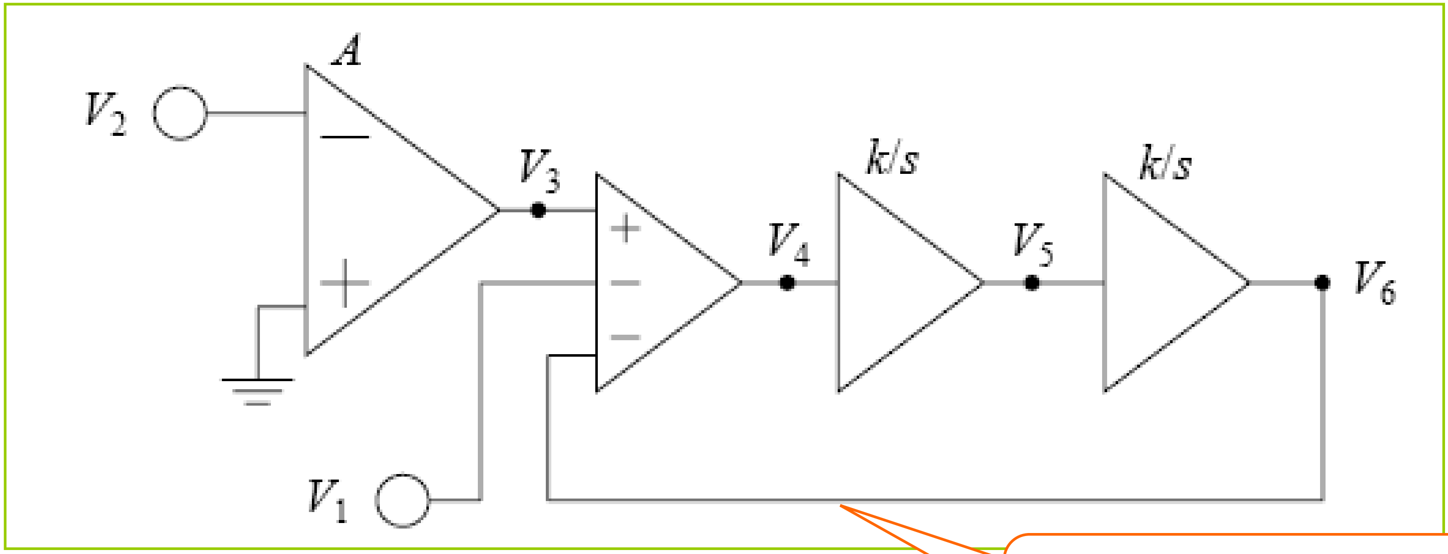
- Tolerancije vrednosti kondenzator 30%
- Relativan odnos r_s je sa tolerancijama 0.1%

Zavisi od tolerancija takta

$$\omega_p = \frac{1}{R_1 C_2} = \frac{1}{\frac{1}{C_1 f_{CLK}} C_2} = \frac{C_1}{C_2} f_{CLK} = r_c f_{CLK}$$

$$\left| S_{\omega_p}^{M(\omega)}(\omega) \right|_{\max} \approx Q_p \left| S_{Q_p}^{M(\omega)}(\omega) \right|_{\max}$$

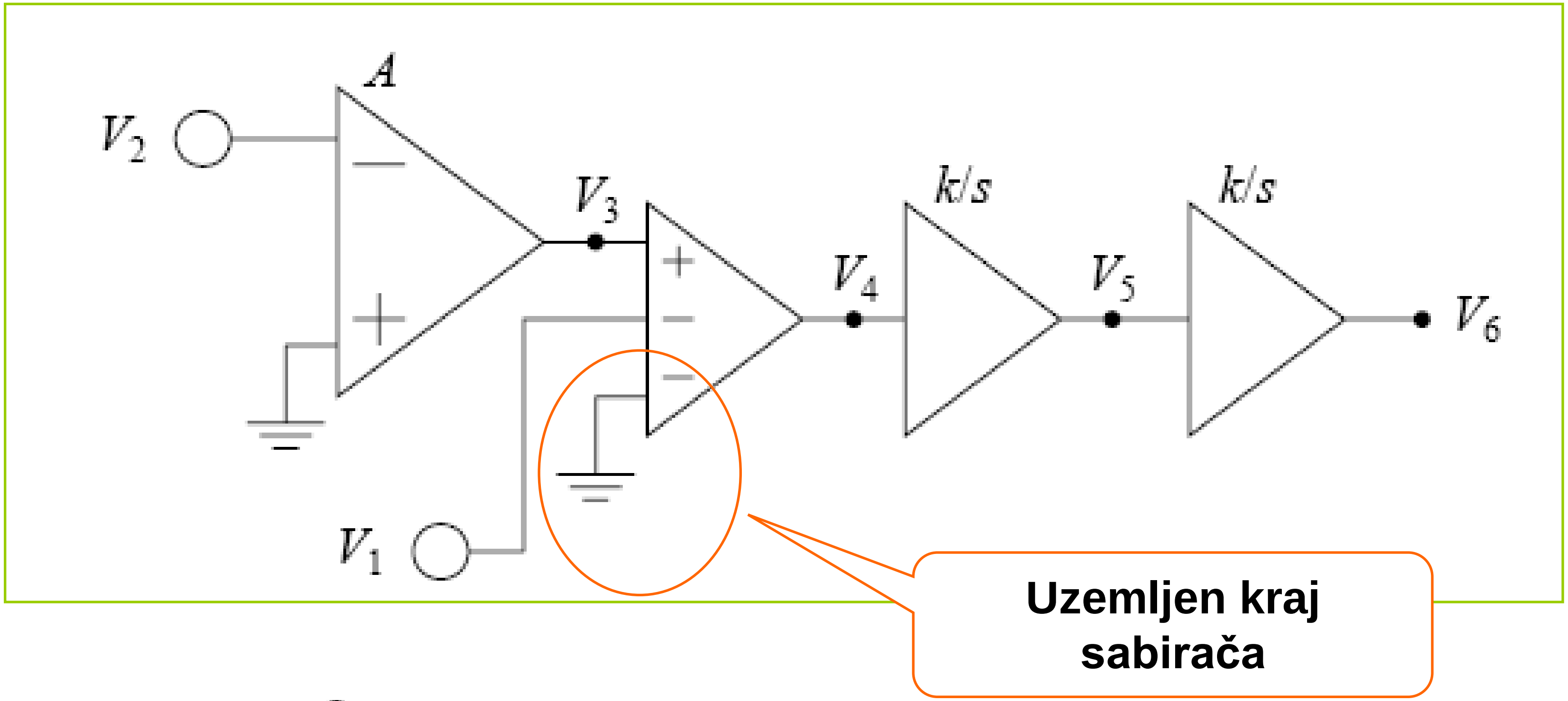
Univerzalno IC (1)



Sa povratnom spregom

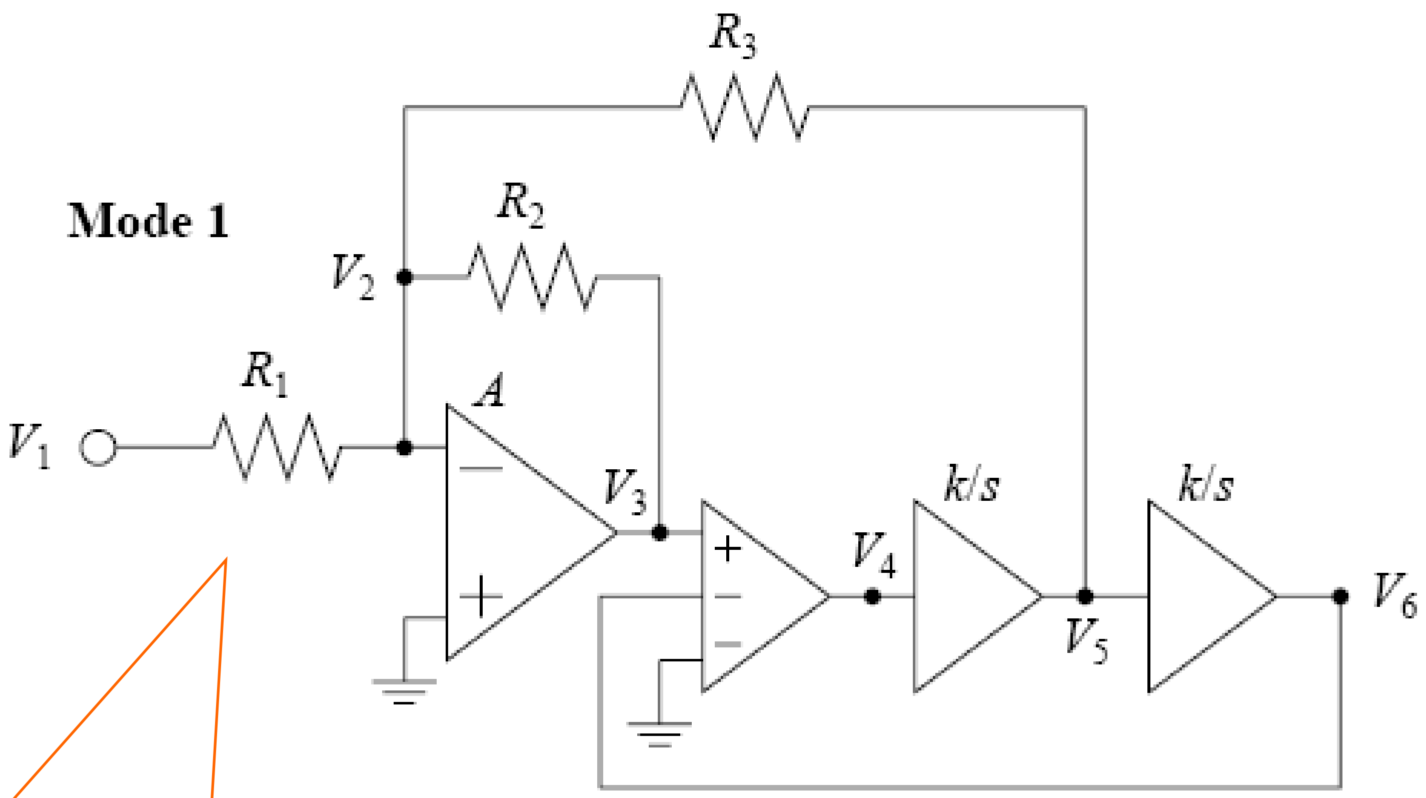
$$k = \frac{2\pi}{P} f_{CLK}, \qquad P = 50 \quad \text{or} \quad P = 100$$

Univerzalno IC (2)



$$k = \frac{2\pi}{P} f_{CLK}, \qquad P = 50 \quad \text{or} \quad P = 100$$

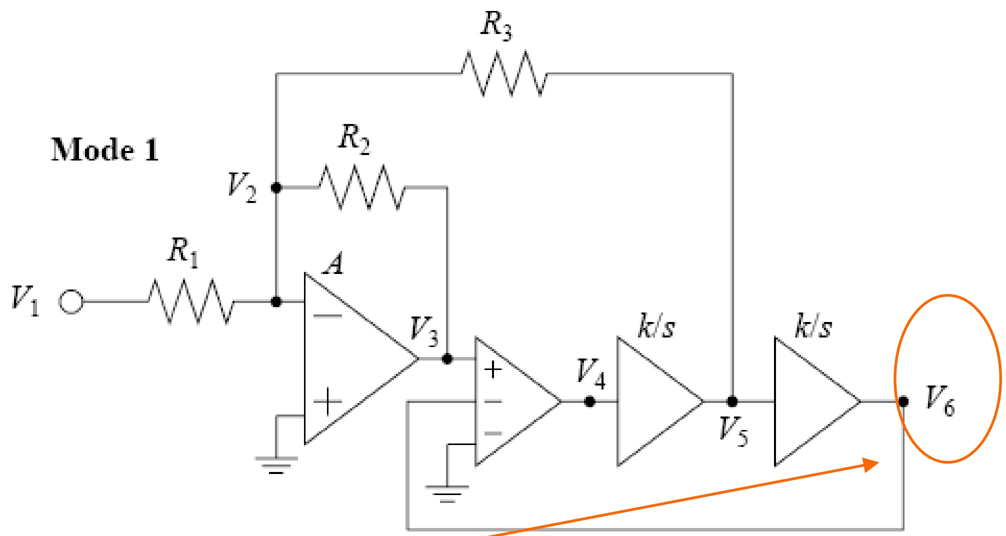
Mode 1 SC biquad



gain-sensitivity product of the pole magnitude to the gain of the operational amplifier = 0

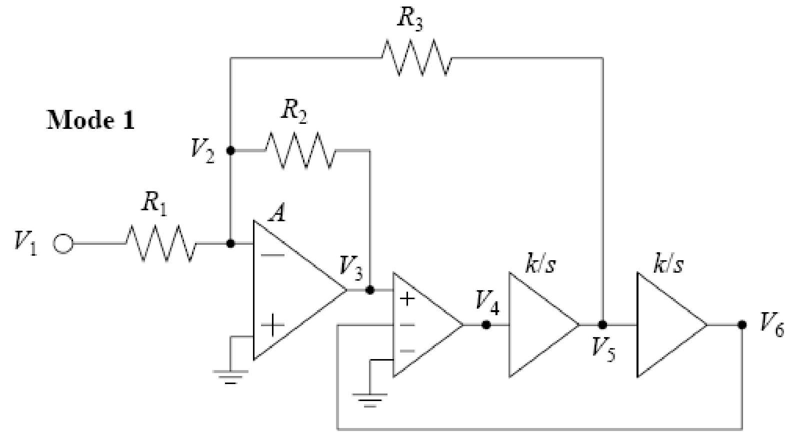
implementation of SC filters at higher frequencies

Propusnici niskih učestanosti

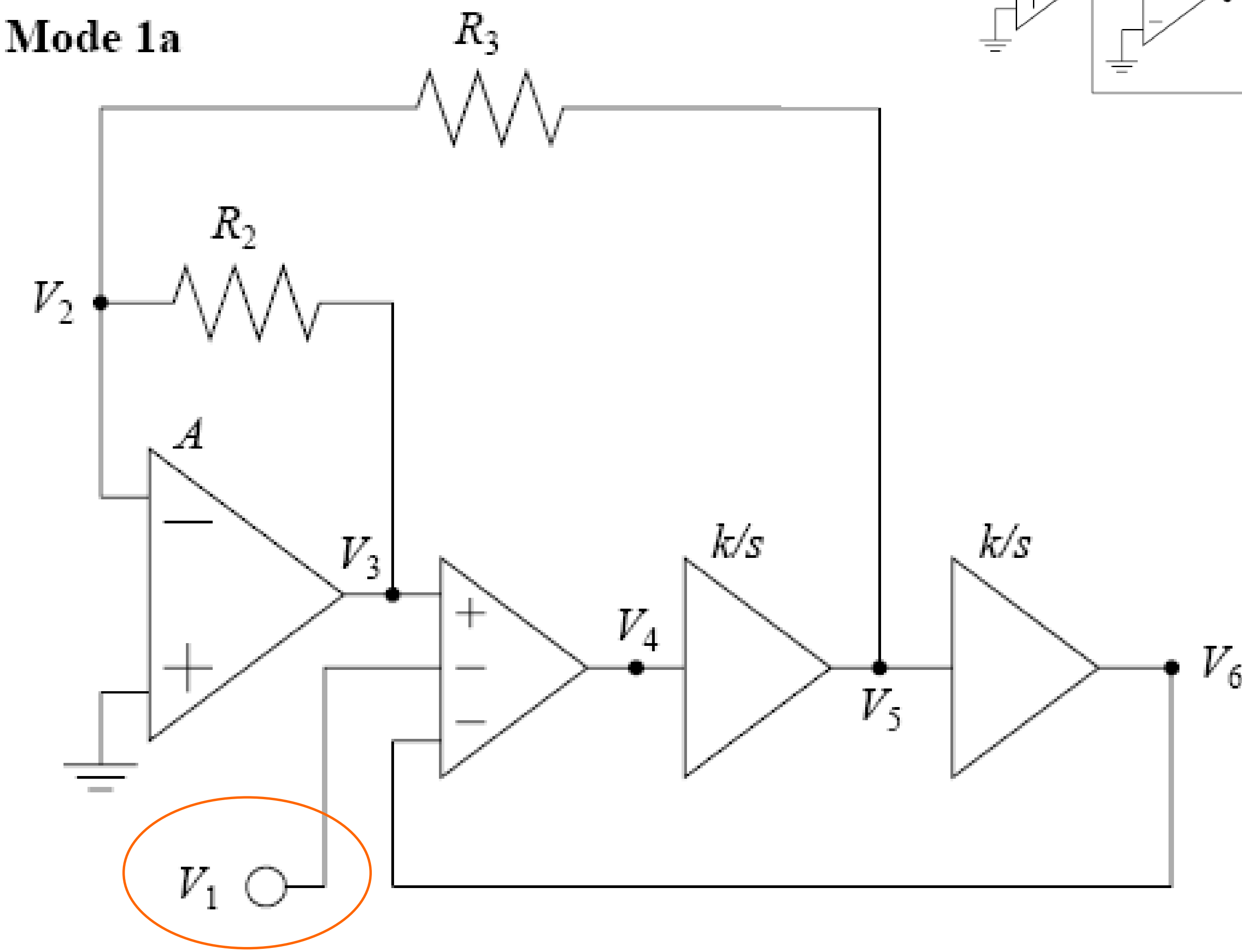


Mode	$\frac{V_6}{V_1}$	$\frac{V_5}{V_1}$
1, 1a, 1b, 1c, 1d, 2, 2a, 2b, 3, 3a, 4, 4a, 5	$H_{LP} = K \frac{\omega_p^2}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$	$H_{BP} = K \frac{\frac{\omega_p}{Q_p}s}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$
6a, 6b, 7	Not applicable	$H_{LP} = K \frac{\omega_p}{s + \omega_p}$

Mode 1a

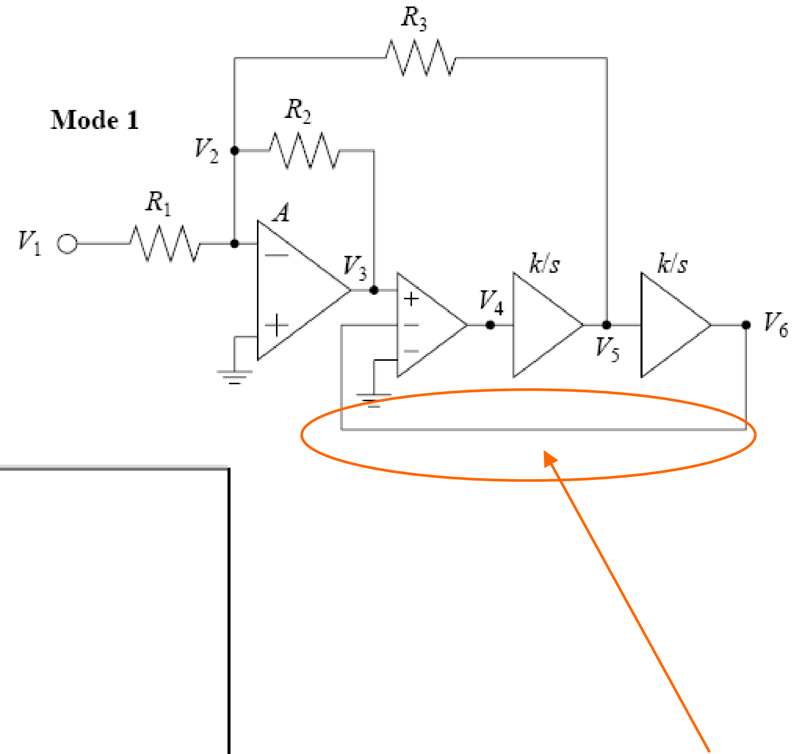


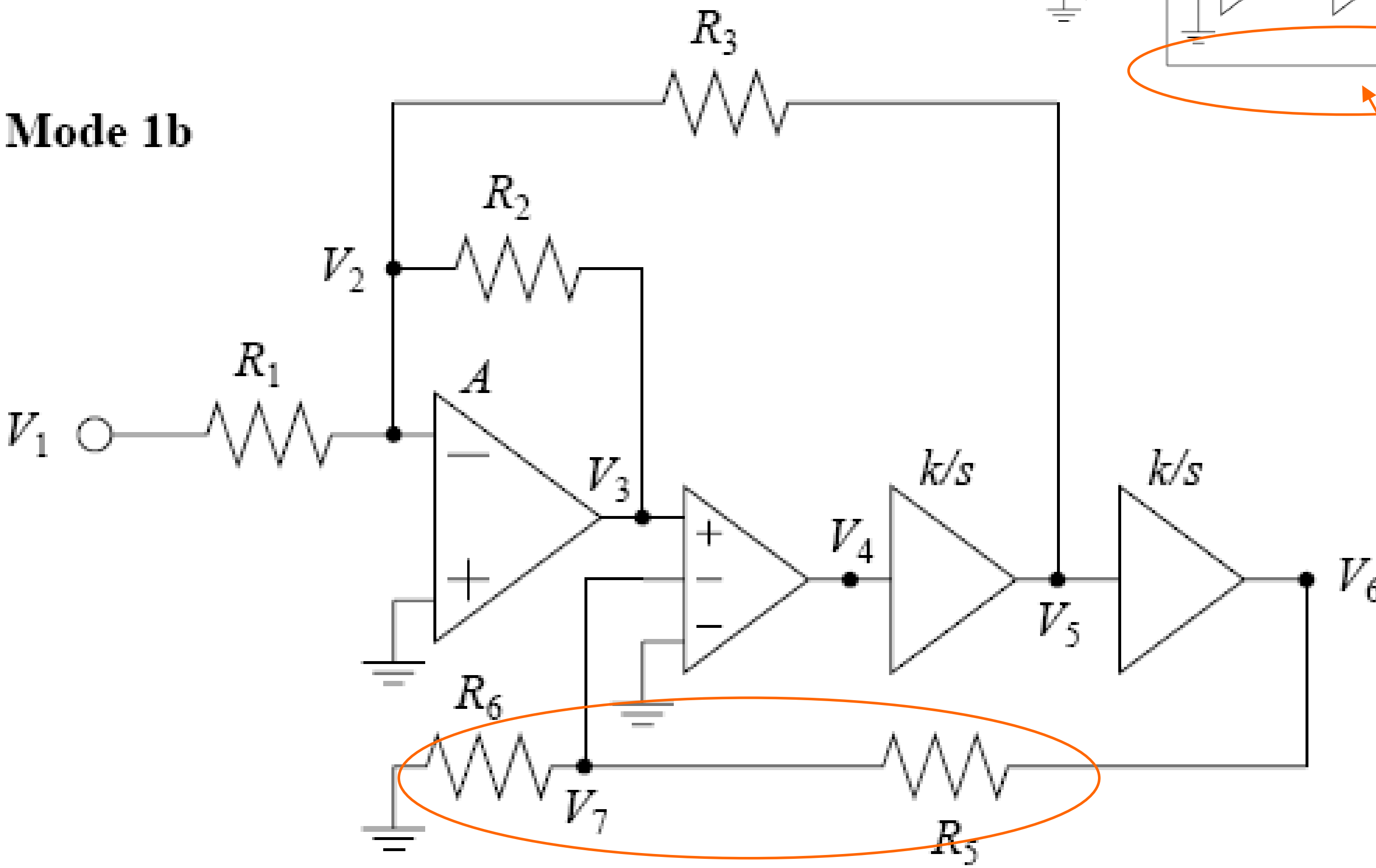
Mode 1
R3
R2
V2
R1
V1
A
V3
V4
k/s
V5
k/s
V6



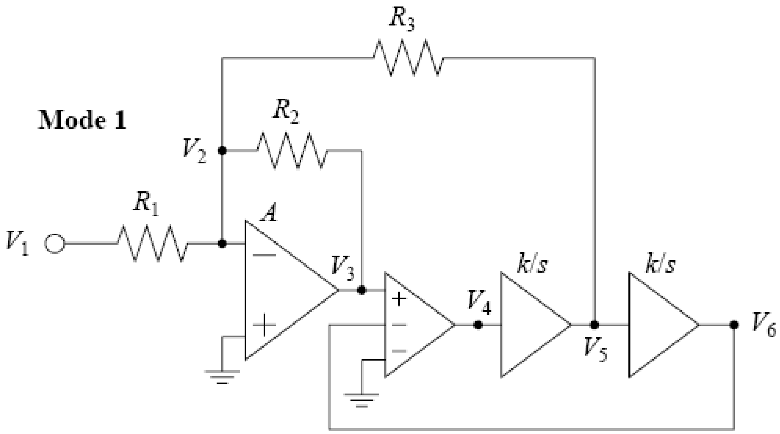
Mode 1a
R3
R2
V2
A
V3
V4
k/s
V5
k/s
V6
V1

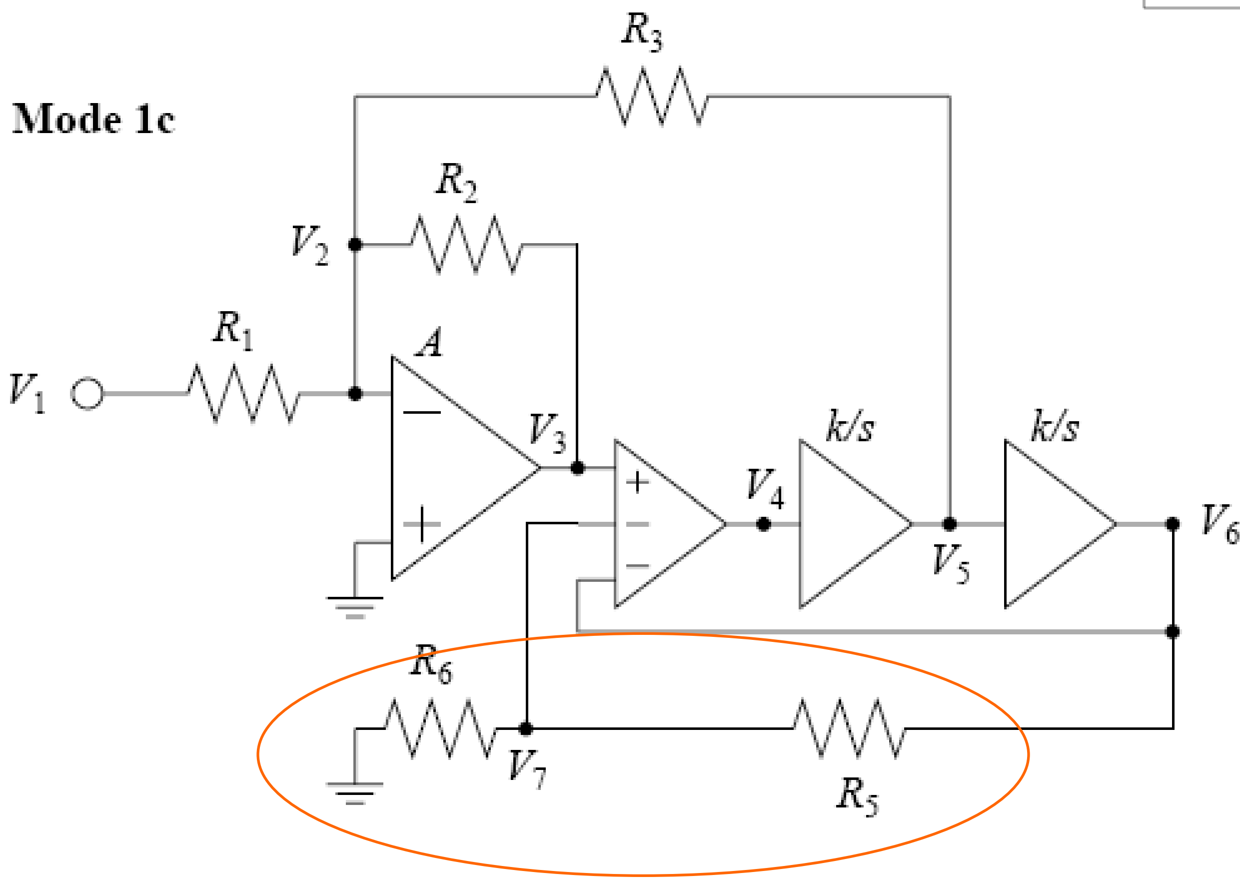
Mode 1b


Mode 1
R_3
R_2
V_2
R_1
A
V_1
V_3
k/s
k/s
V_4
V_5
V_6

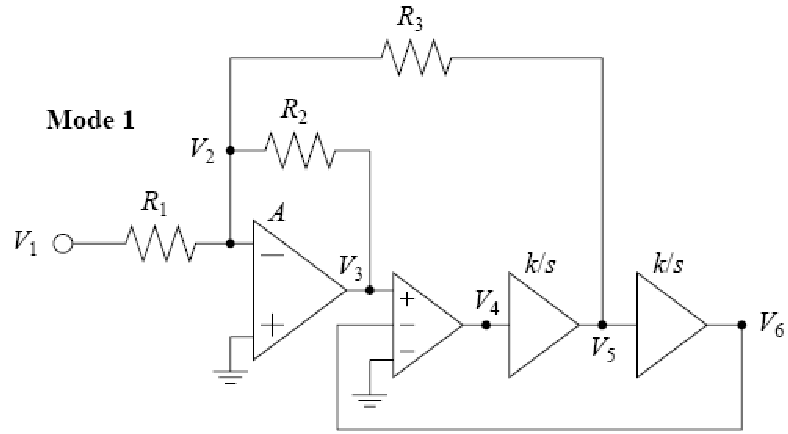

Mode 1b
R_3
R_2
V_2
R_1
A
V_1
V_3
k/s
k/s
V_4
V_5
V_6
R_6
V_7
R_5

Mode 1c

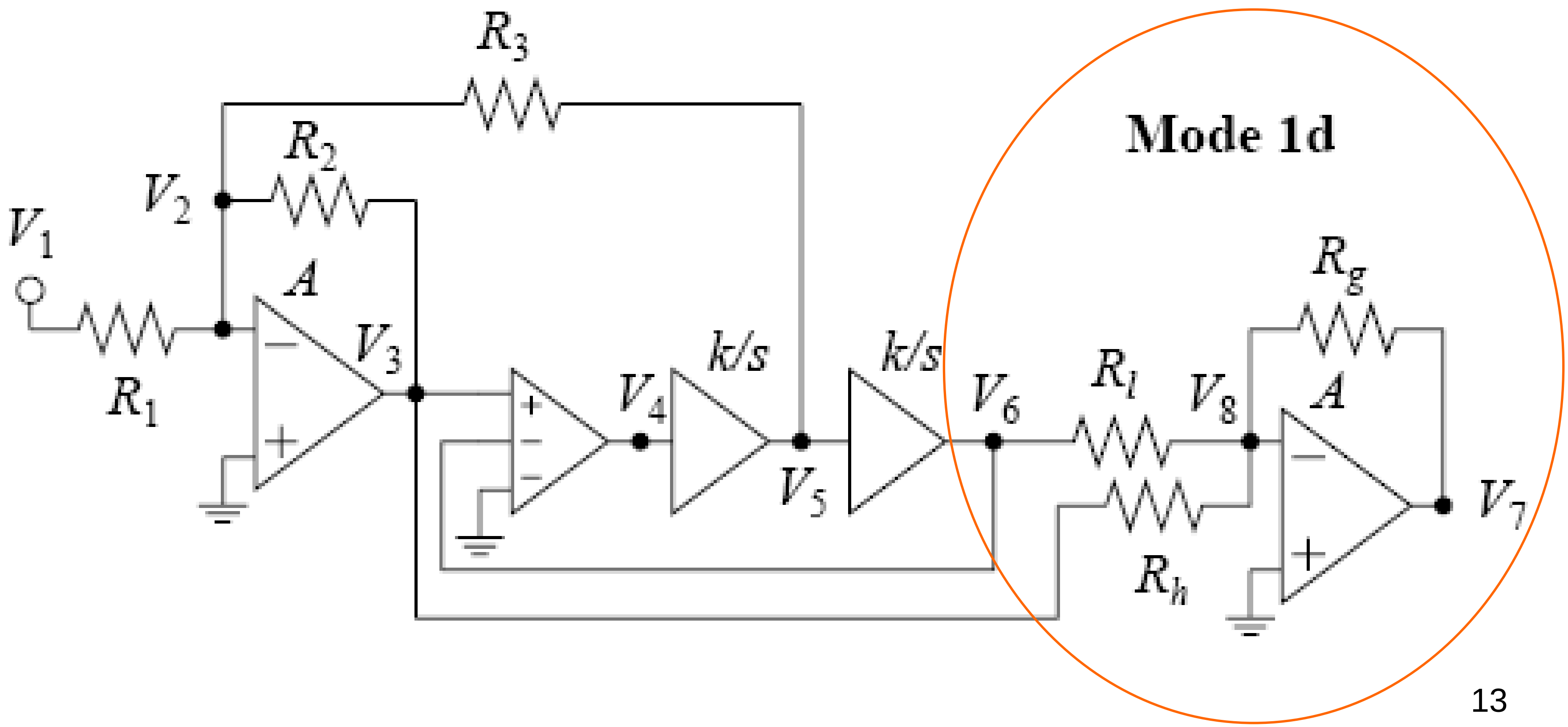

Mode 1
R_3
R_2
V_2
R_1
A
V_1
V_3
V_4
k/s
k/s
V_5
V_6


Mode 1c
R_3
R_2
V_2
R_1
A
V_1
V_3
V_4
k/s
k/s
V_5
V_6
R_6
V_7
R_5

Mode 1d

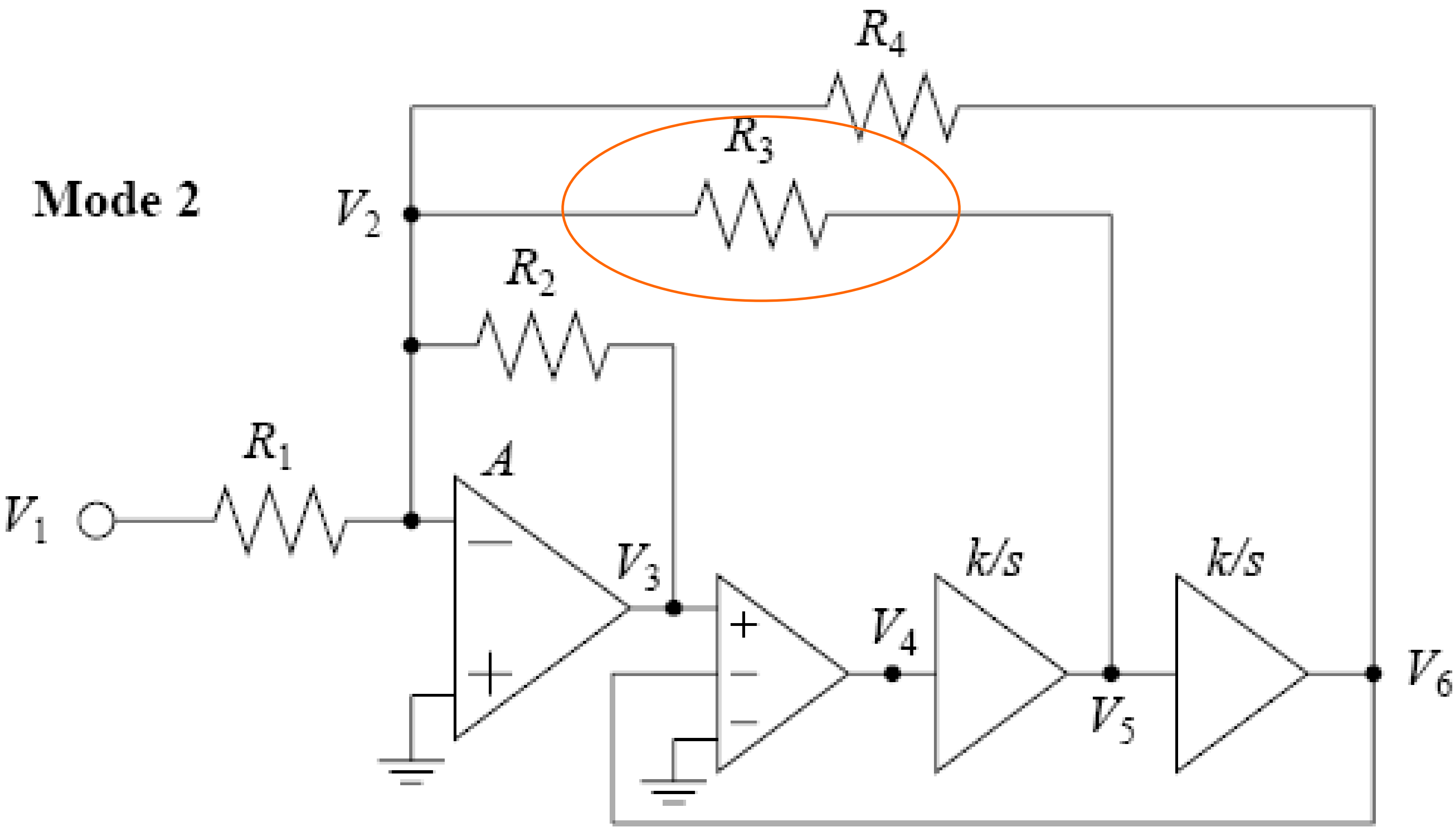


Mode 1
R_3
R_2
V_2
R_1
V_1
A
V_3
V_4
k/s
k/s
V_5
V_6

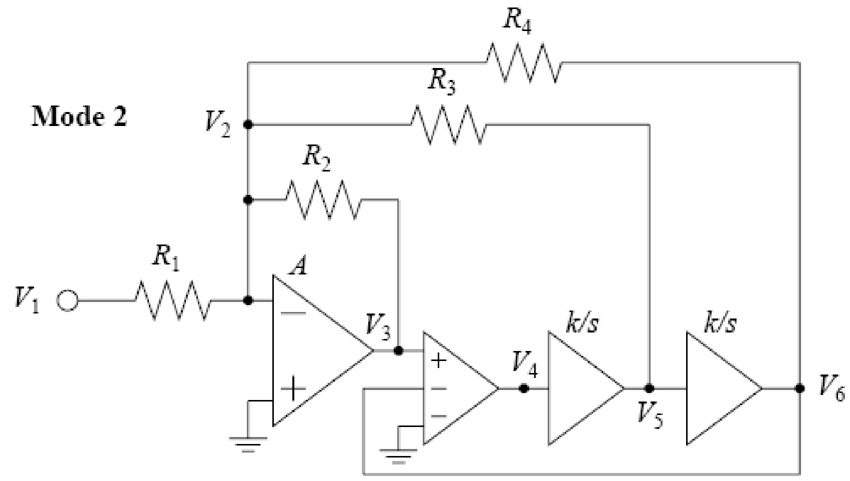


R_3
R_2
V_2
V_1
A
R_1
V_3
V_4
k/s
V_5
k/s
V_6
Mode 1d
R_g
R_l
V_8
A
V_7
R_h

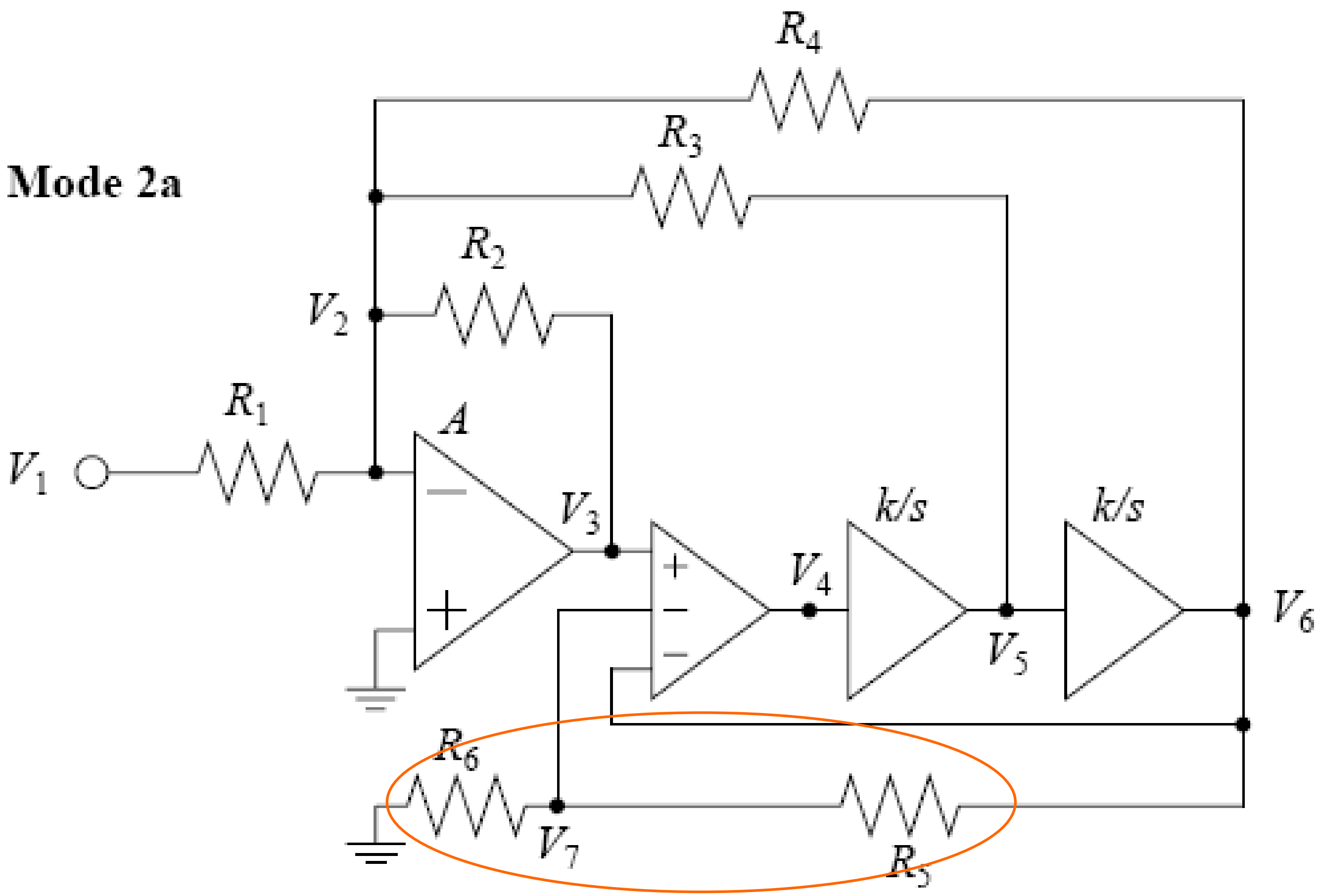
Mode 2



Mode 2a

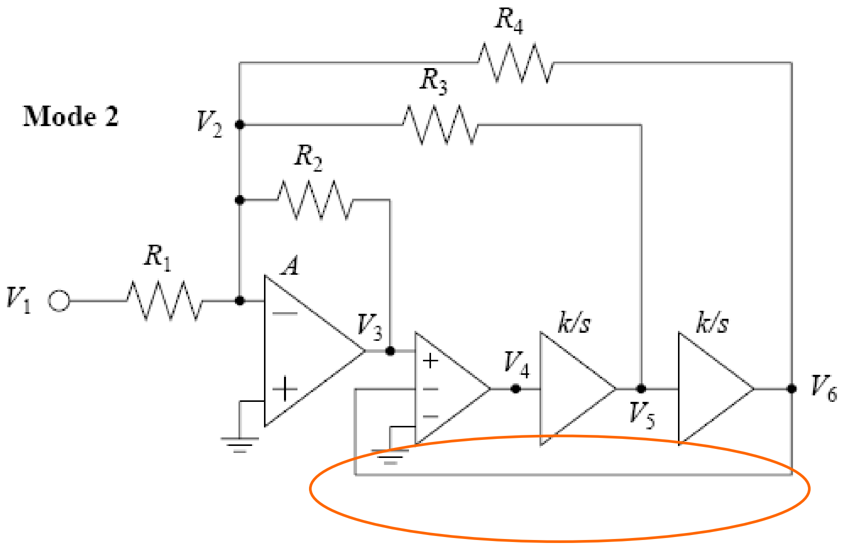


Mode 2
R_4
R_3
V_2
R_2
R_1
A
V_1
V_3
V_4
k/s
k/s
V_5
V_6

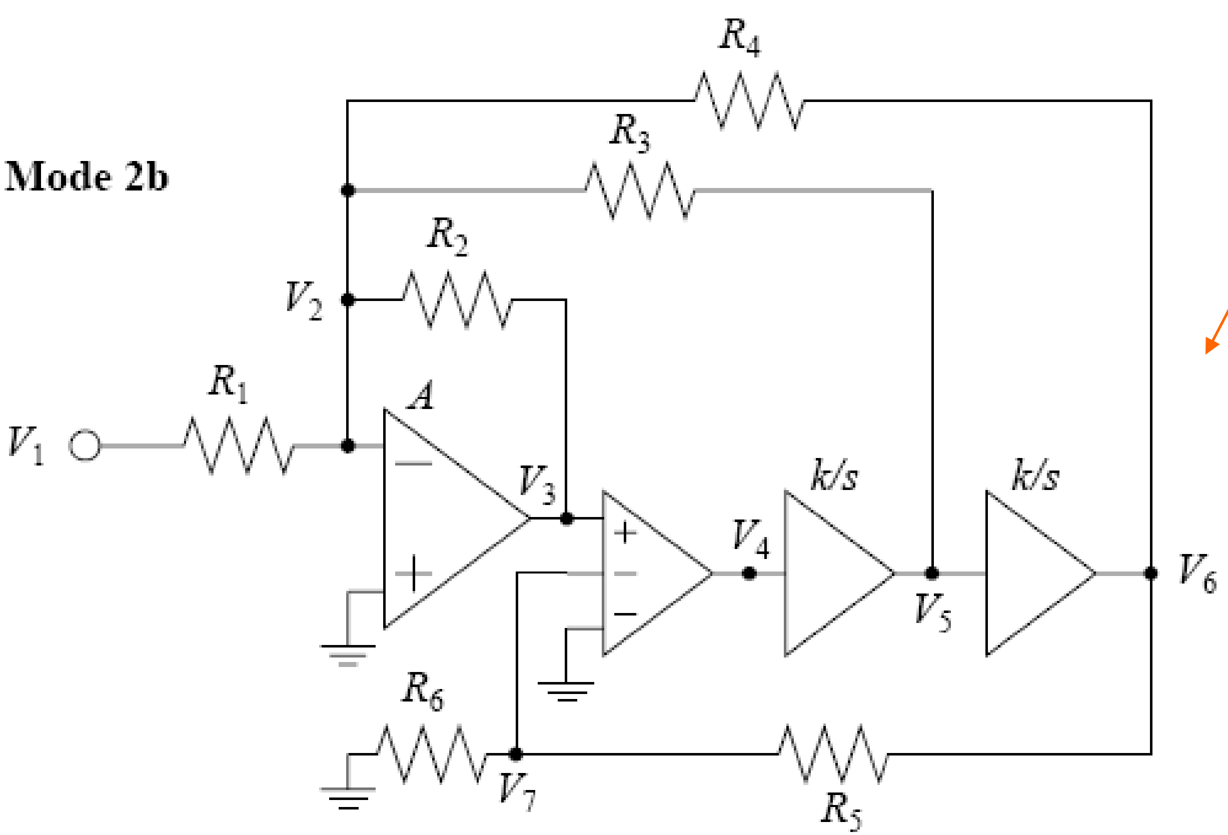


Mode 2a
R_4
R_3
R_2
V_2
R_1
A
V_1
V_3
k/s
k/s
V_4
V_5
V_6
R_6
V_7
R_5

Mode 2b

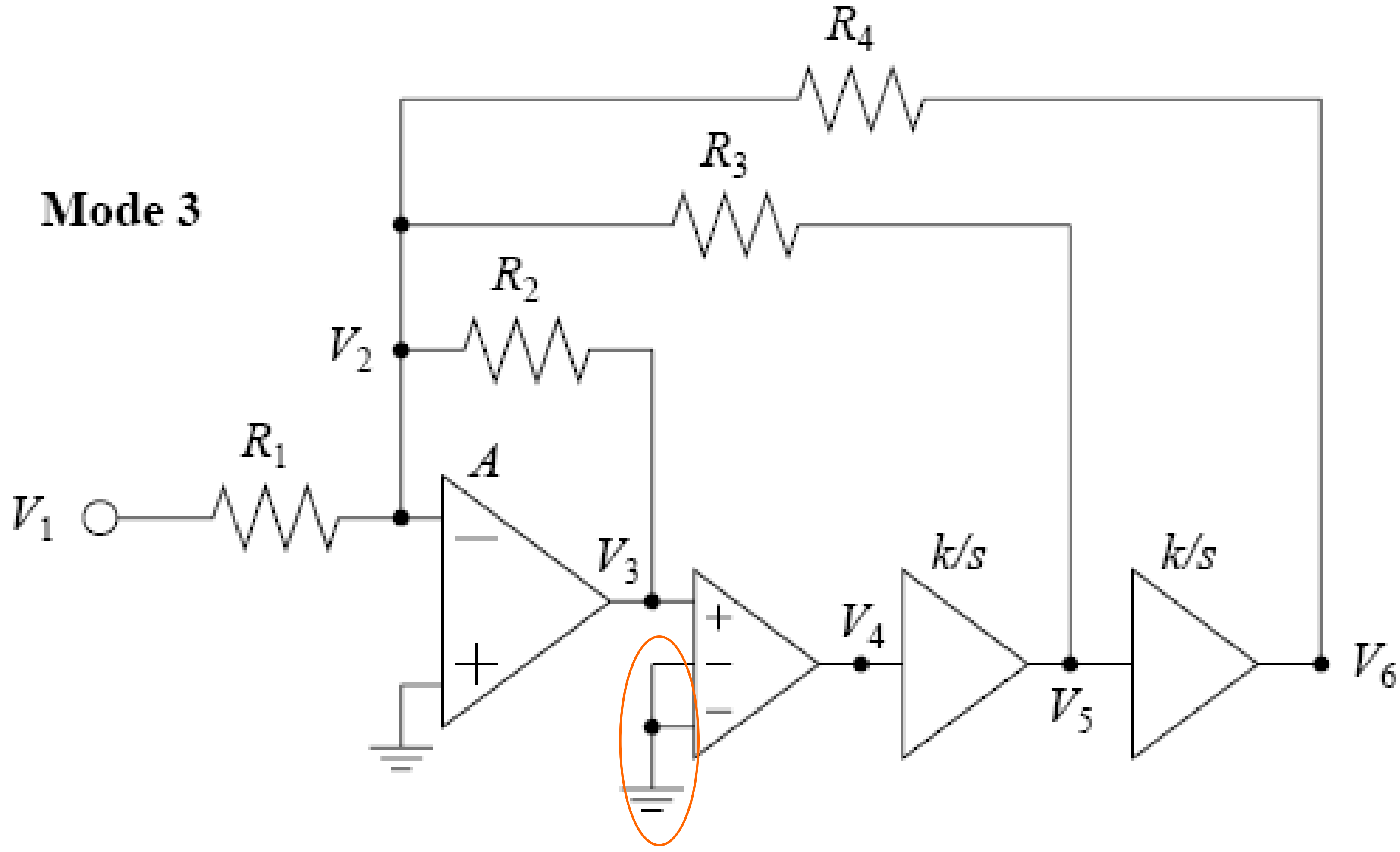


Mode 2
R_4
R_3
V_2
R_2
R_1
A
V_1
V_3
k/s
k/s
V_4
V_6
V_5

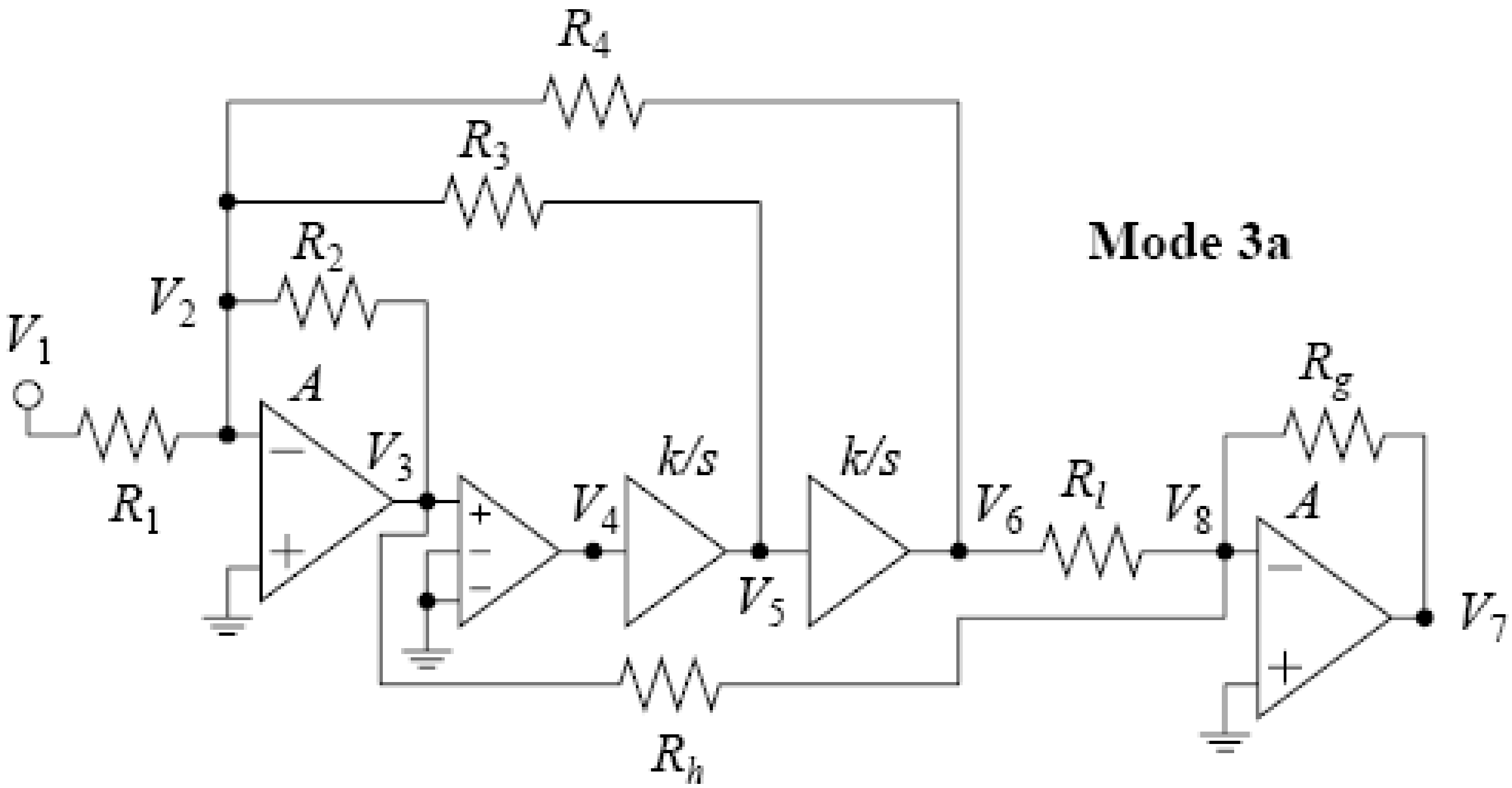


R_4
Mode 2b
R_3
R_2
V_2
R_1
A
V_1
V_3
k/s
k/s
V_4
V_6
V_5
R_6
V_7
R_5

Mode 3

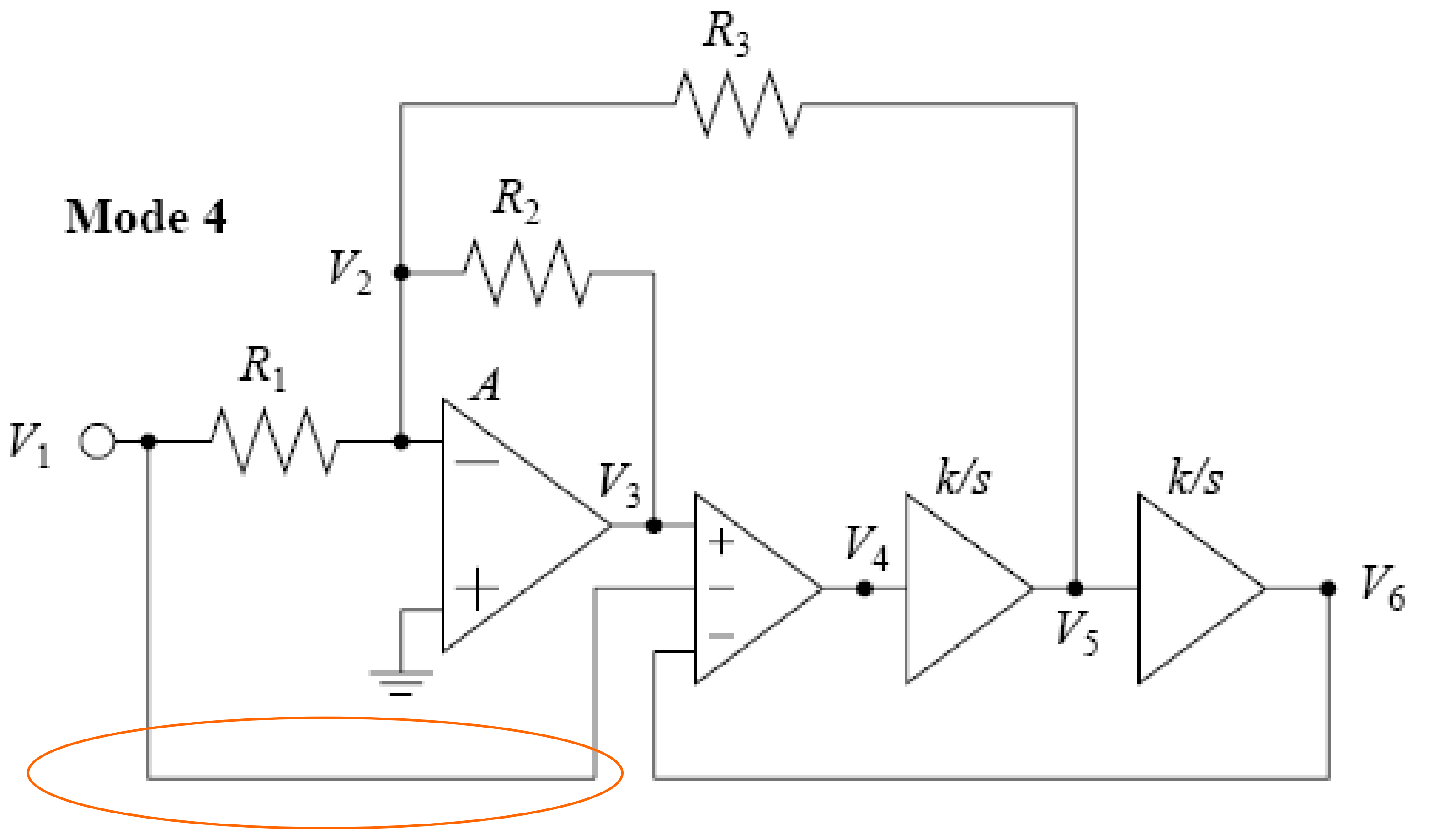


Mode 3a

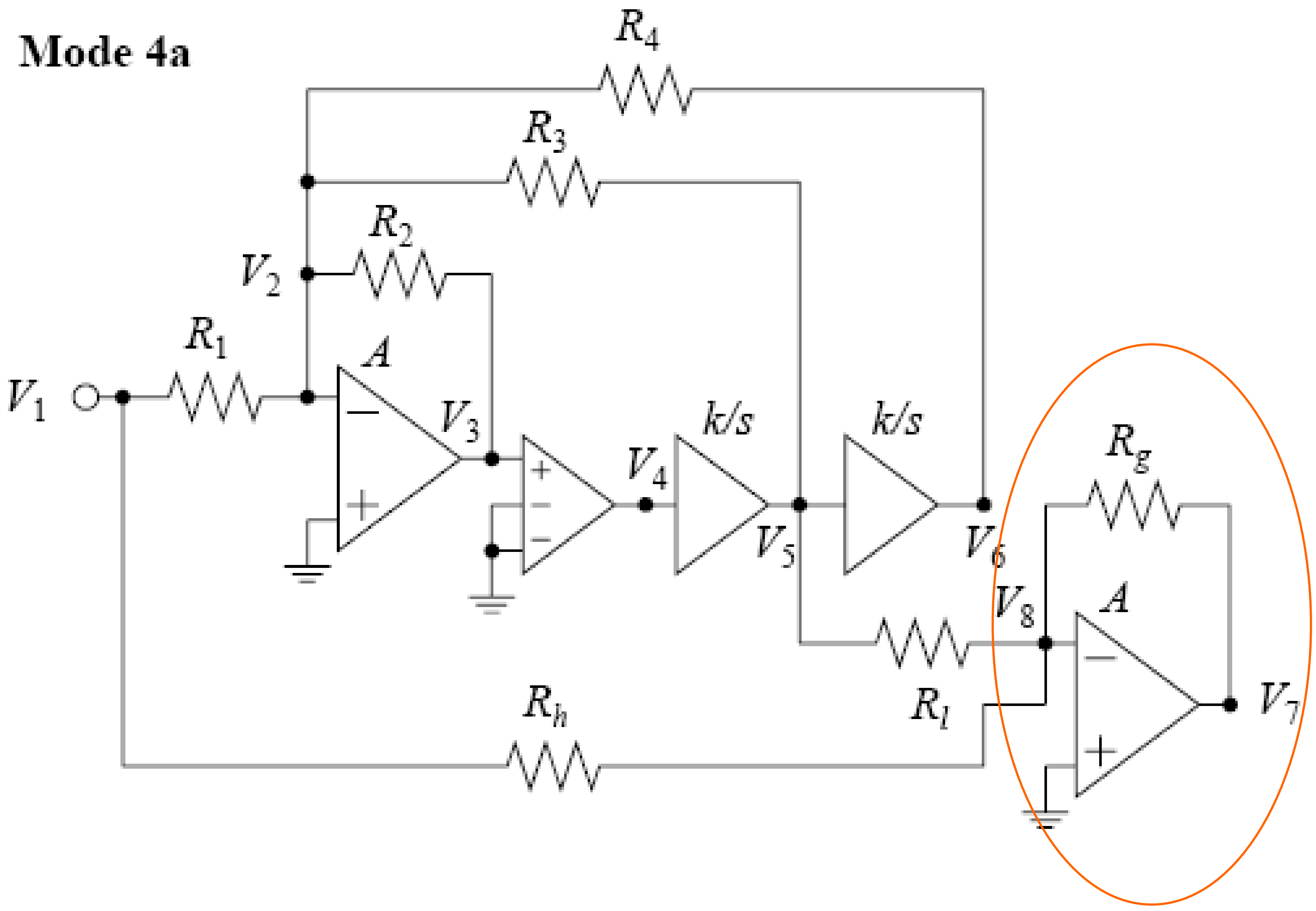


Mode 4

$$\omega_p = \frac{2\pi}{P} f_{CLK}$$



Mode 4a



Mode 5

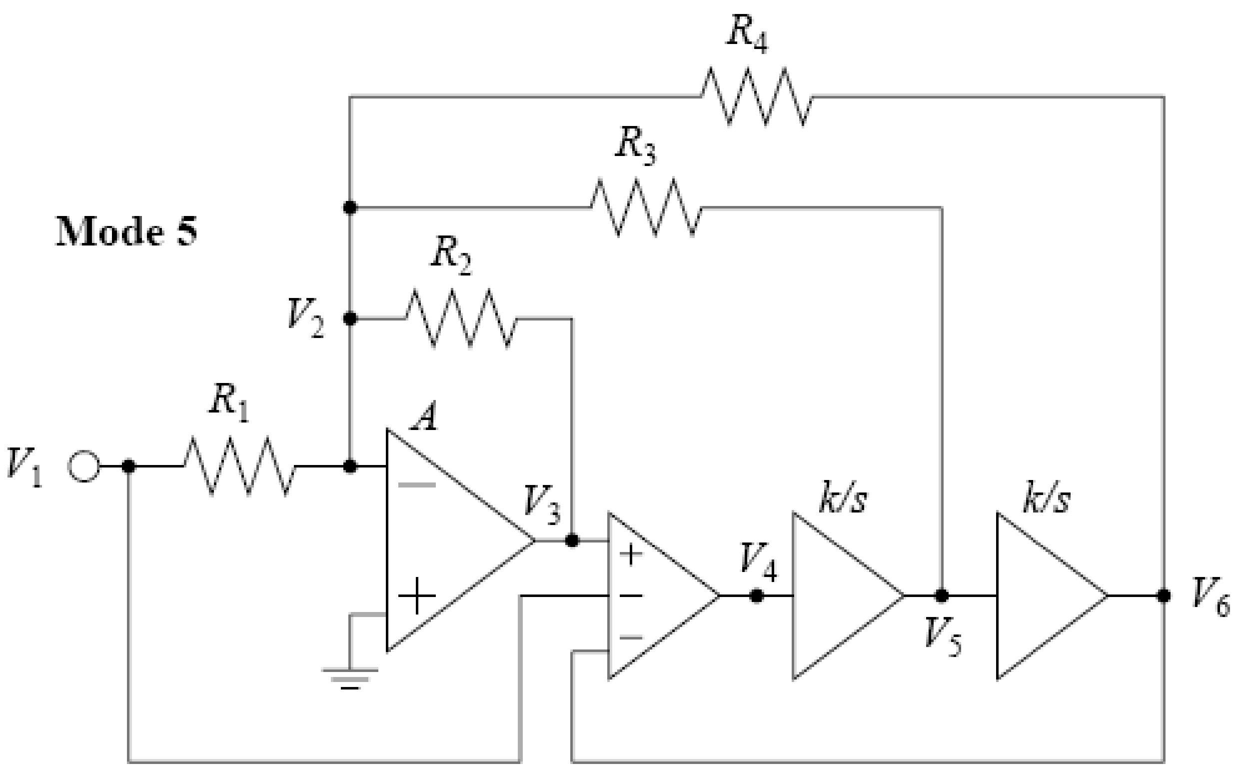
$$H_{CZ} = K \frac{s^2 + \frac{\omega_z}{Q_z} s + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}, \qquad \omega_z < \omega_p$$

$$\omega_p = \frac{2\pi f_{CLK}}{P} \sqrt{1 + \frac{R_2}{R_4}}$$

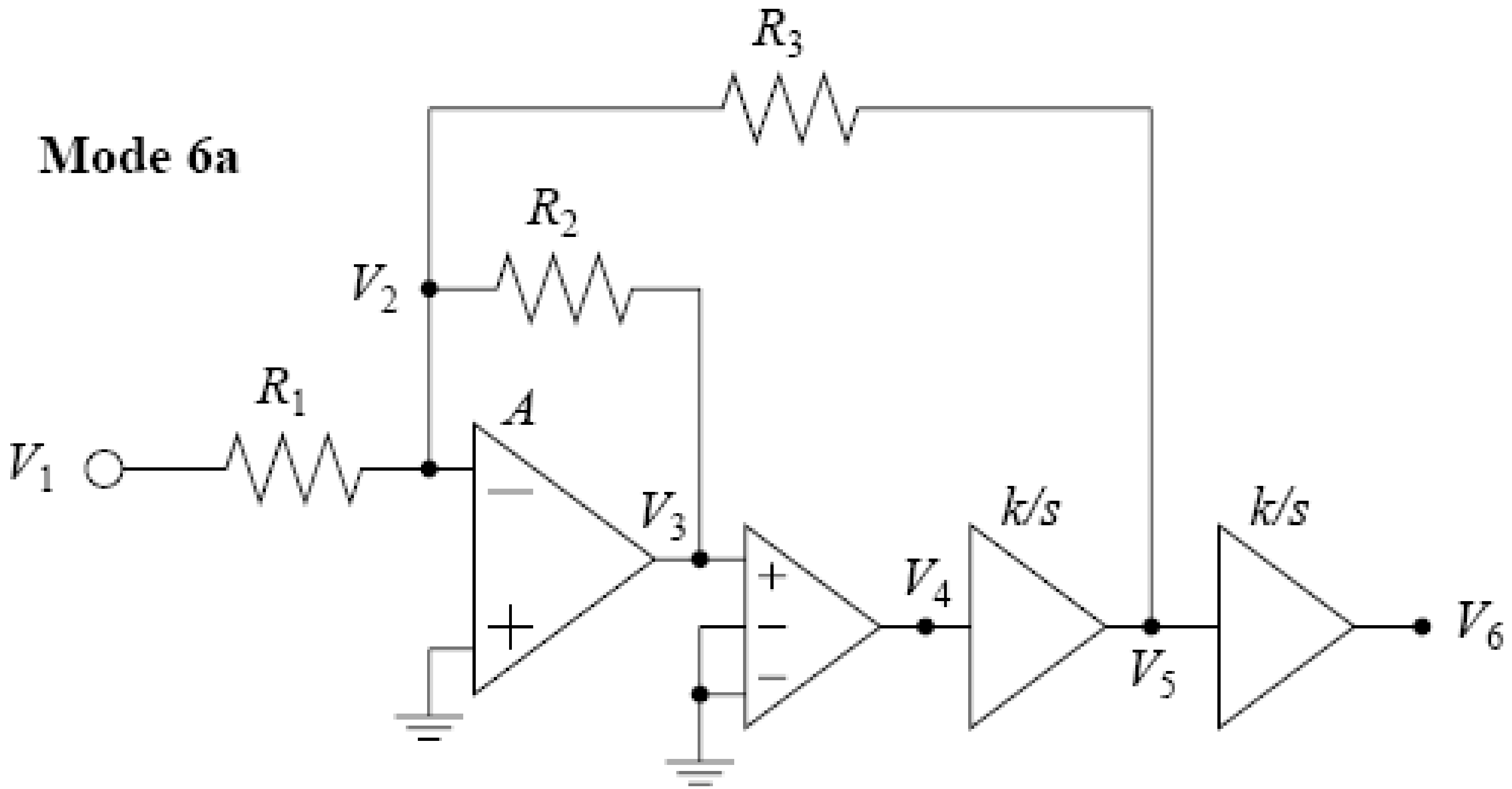
$$\omega_z = \frac{2\pi f_{CLK}}{P} \sqrt{1 - \frac{R_1}{R_4}}$$

$$Q_p = \frac{R_3}{R_4} \sqrt{1 + \frac{R_2}{R_4}}$$

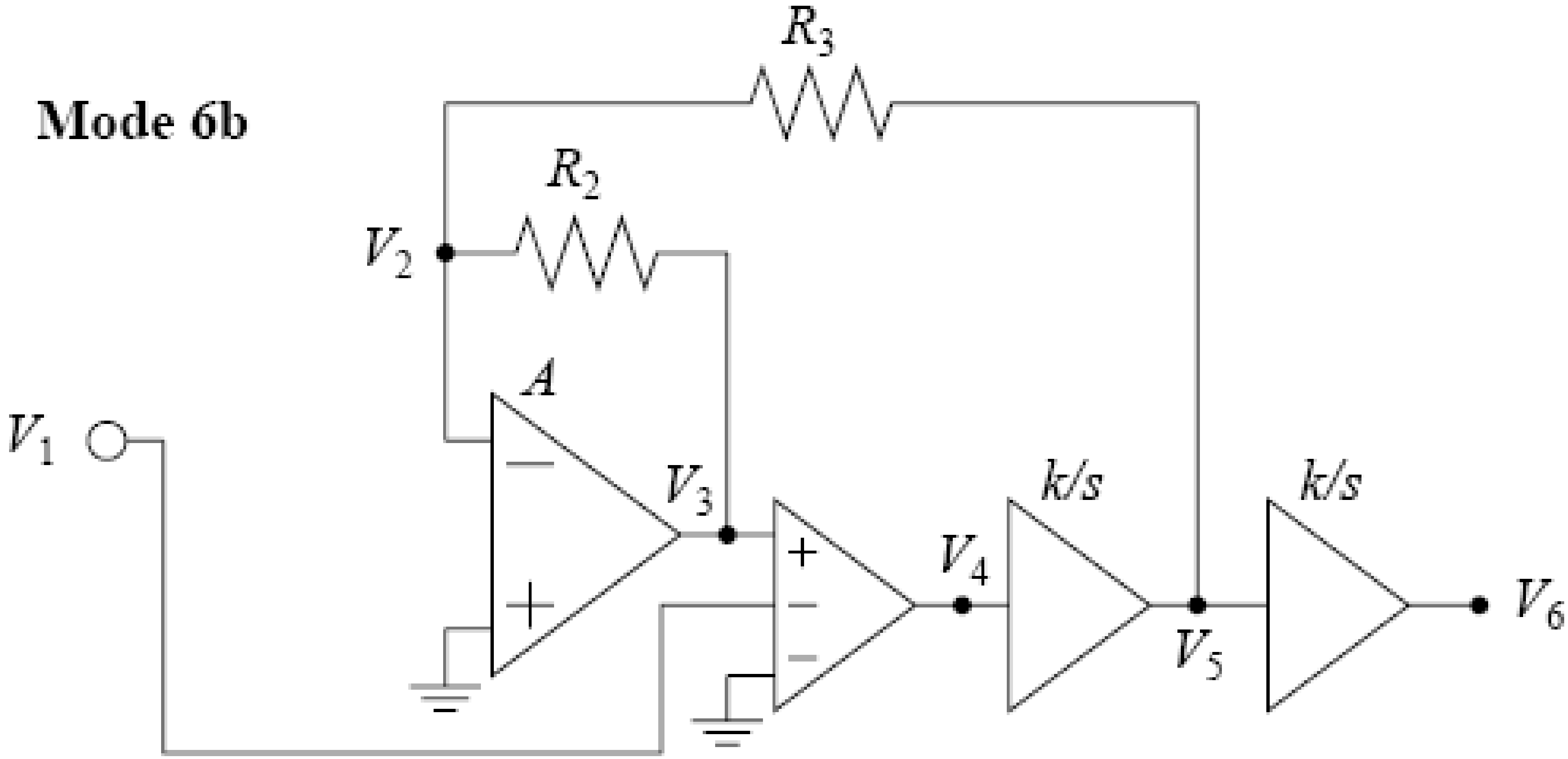
$$Q_z = \frac{R_3}{R_1} \sqrt{1 - \frac{R_1}{R_4}}$$



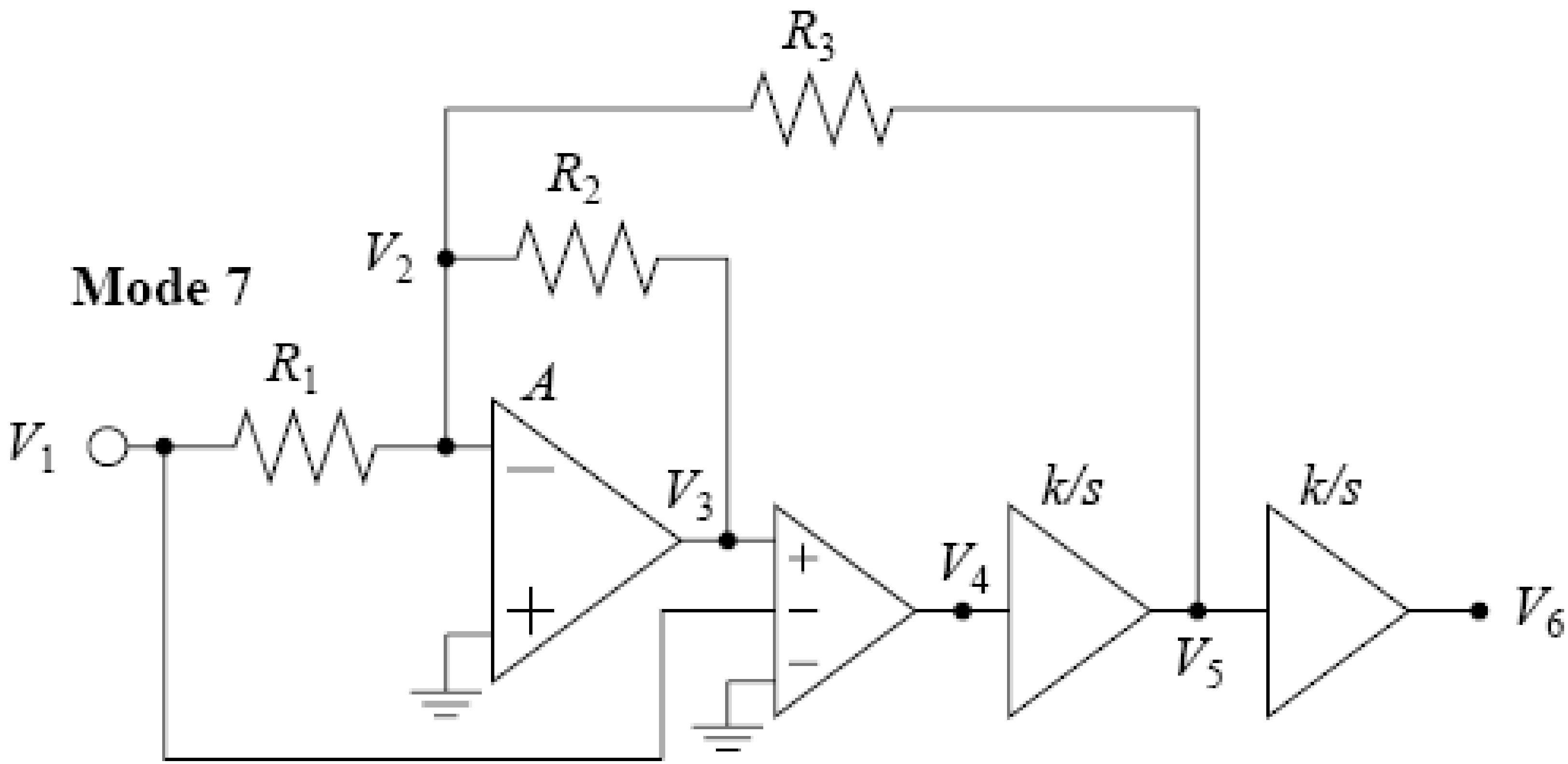
Mode 6a



Mode 6b



Mode 7



LP

Mode	$\frac{V_6}{V_1}$	$\frac{V_5}{V_1}$
1, 1a, 1b, 1c, 1d, 2, 2a, 2b, 3, 3a, 4, 4a, 5	$H_{LP} = K \frac{\omega_p^2}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$	$H_{BP} = K \frac{\frac{\omega_p}{Q_p}s}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$
6a, 6b, 7	Not applicable	$H_{LP} = K \frac{\omega_p}{s + \omega_p}$

HP

Mode	$H_{HP} = \frac{V_3}{V_1} = K \frac{s^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$
3	$\omega_p = \frac{2\pi f_{CLK}}{P} \sqrt{\frac{R_2}{R_4}}$

BR

Mode	$H_{BR} = \frac{V_3}{V_1} = K \frac{s^2 + \omega_p^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$
1	$\omega_p = \frac{2\pi f_{CLK}}{P}$
1b	$\omega_p = \frac{2\pi f_{CLK}}{P} \sqrt{\frac{R_6}{R_5 + R_6}}$
1c	$\omega_p = \frac{2\pi f_{CLK}}{P} \sqrt{1 + \frac{R_6}{R_5 + R_6}}$

AP

Mode	$H_{AP} = \frac{V_3}{V_1} = K \frac{s^2 - \frac{\omega_p}{Q_p}s + \omega_p^2}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$
4	$\omega_p = \frac{2\pi f_{CLK}}{P}$
4a	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_2}{R_4}}$

BP

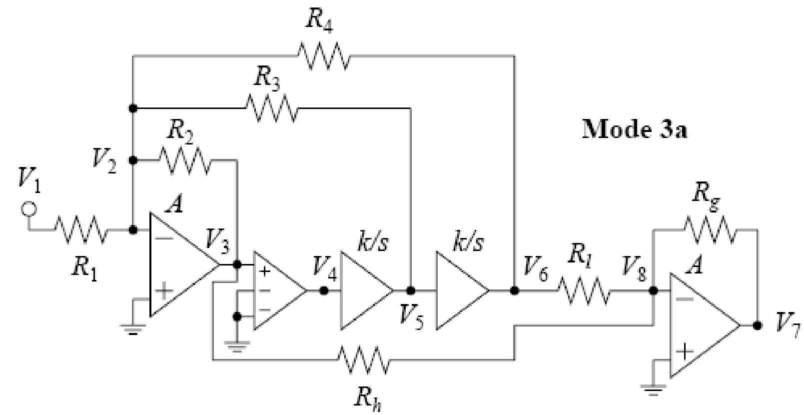
Mode	$H_{BP} = \frac{V_3}{V_1} = K \frac{\frac{\omega_p}{Q_p} s}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$
1a	$\omega_p = \frac{2\pi f_{CLK}}{P}$

HPN

$$H_{HPN} = K\frac{s^2+\omega_z^2}{s^2+\frac{\omega_p}{Q_p}s+\omega_p^2}, \quad \omega_z < \omega_p$$

Mode	$H_{HPN} = \frac{V_3}{V_1} = K\frac{s^2+\omega_z^2}{s^2+\frac{\omega_p}{Q_p}s+\omega_p^2}$	$\frac{R_2}{R_4} > \frac{R_h}{R_l}$
2	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{1+\frac{R_2}{R_4}}$	$\omega_z = \frac{2\pi f_{CLK}}{P}$
2a	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_2}{R_4}+\frac{R_5+2R_6}{R_5+R_6}}$	$\omega_z = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_5+2R_6}{R_5+R_6}}$
2b	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_2}{R_4}+\frac{R_6}{R_5+R_6}}$	$\omega_z = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_6}{R_5+R_6}}$
3a	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_2}{R_4}}$	$\omega_z = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_h}{R_l}}$

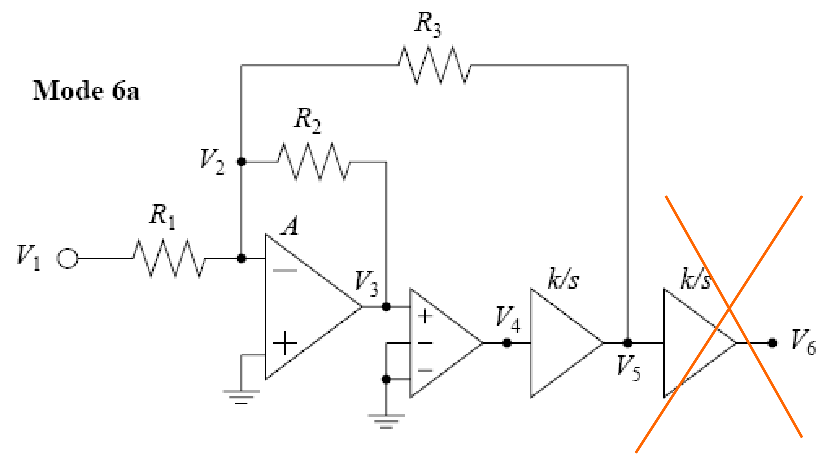
LPN



Mode		
	$H_{LPN} = \frac{V_3}{V_1} = K\frac{s^2 + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$	$\frac{R_2}{R_4} < \frac{R_h}{R_l}$
1d	$\omega_p = \frac{2\pi f_{CLK}}{P}$	$\omega_z = \frac{2\pi f_{CLK}}{P}\sqrt{1 + \frac{R_h}{R_l}}$
3a	$\omega_p = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_2}{R_4}}$	$\omega_z = \frac{2\pi f_{CLK}}{P}\sqrt{\frac{R_h}{R_l}}$

$$H_{LPN} = K\frac{s^2 + \omega_z^2}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}, \quad \omega_z > \omega_p$$

Prvog reda



Mode	Transfer function	Pole magnitude
6a	$H_{HP} = \frac{V_3}{V_1} = K\frac{s}{s+\omega_p}$	$\omega_p = \frac{2\pi f_{CLK}}{P}\frac{R_2}{R_3}$
6b	$H_{LP} = \frac{V_3}{V_1} = K\frac{\omega_p}{s+\omega_p}$	$\omega_p = \frac{2\pi f_{CLK}}{P}\frac{R_2}{R_3}$
7	$H_{AP} = \frac{V_3}{V_1} = K\frac{s-\omega_p}{s+\omega_p}$	$\omega_p = \frac{2\pi f_{CLK}}{P}\frac{R_2}{R_3}$

Simbolička analiza

CAF_SC_Mode3a.nb

Classical Analog Filter Design

Switched Capacitor Filter

Mode 3a

Analysis and Design

Miroslav D. Lutovac

References

- **M. Lutovac, D. Tosic and B. Evans,"Advanced Filter Design for Signal Processing using MATLAB and Mathematica"**

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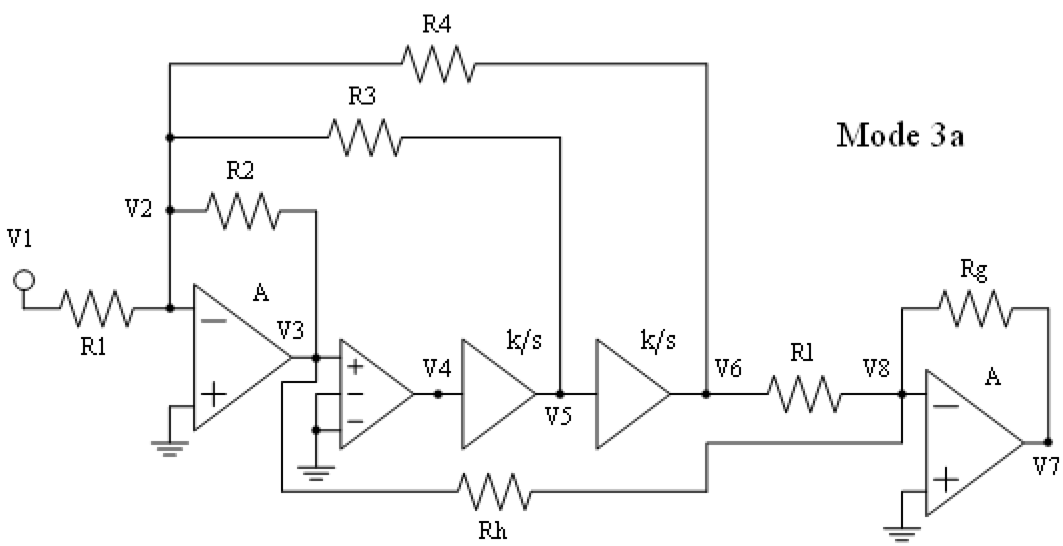
Crtanje šeme

CAF_SC_Mode3a.nb

```
In[1]:= << "C:\\aalm\\ETF_predavanja\\Filtri\\mathematica\\clearall.m"
        << "C:\\aalm\\ETF_predavanja\\Filtri\\mathematica\\drawafil.m"
        << "C:\\aalm\\ETF_predavanja\\Filtri\\mathematica\\drawasc.m"
```

In[4]:= DrawMode3a$\left[0,\ 0,\ \frac{1}{2},\ \frac{5}{4},\ 8\right]$

Out[4]=



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Postavljanje jednačina

CAF_SC_Mode3a.nb

Circuit Analysis

- **Reduced Modified Nodal Analysis**

```
In[5]:= CircuitEquations = {V1 == Vg,
          (V2 - V1)/R1 + (V2 - V3)/R2 + (V2 - V5)/R3 + (V2 - V6)/R4 == 0,
          V3 == -A V2, V4 == V3,
          V5 == (V4 k)/s,
          V6 == (V5 k)/s,
          (V8 - V6)/Rl + (V8 - V3)/Rh + (V8 - V7)/Rg == 0,
          V7 == -A V8};
        NodeVoltages = {V1, V2, V3, V4, V5, V6, V7, V8};
        CircuitResponse =
          Together[Flatten[Solve[CircuitEquations, NodeVoltages]]];
        Print["V1 = ", V1 /. CircuitResponse]
        Print["V7 = ", V7 /. CircuitResponse]
```

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Određivanje funkcije prenosa

CAF_SC_Mode3a.nb

```
Print["V1 = ", V1 /. CircuitResponse]
Print["V7 = ", V7 /. CircuitResponse]
```

V1 = Vg

$$V7 = \left(A^2\, R2\, R3\, R4\, \left(k^2\, Rg\, Rh + Rg\, R1\, s^2\right) Vg\right) / \left(\left(Rg\, Rh + Rg\, R1 + Rh\, R1 + A\, Rh\, R1\right) \left(A\, k^2\, R1\, R2\, R3 + A\, k\, R1\, R2\, R4\, s + R1\, R2\, R3\, s^2 + R1\, R2\, R4\, s^2 + R1\, R3\, R4\, s^2 + A\, R1\, R3\, R4\, s^2 + R2\, R3\, R4\, s^2\right)\right)$$

Voltage Transfer Function

```
In[10]:= H = Simplify[Together[V7/V1 /. CircuitResponse]];
H3a = Limit[H, A → ∞];
Print["H(s) = ", Factor[Collect[Numerator[H3a], s]] / Factor[Collect[Denominator[H3a], s]]]
```

$$H(s) = \frac{R2\, R3\, R4\, Rg\, \left(k^2\, Rh + R1\, s^2\right)}{R1\, Rh\, R1\, \left(k^2\, R2\, R3 + k\, R2\, R4\, s + R3\, R4\, s^2\right)}$$

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Definicije promenljivih

CAF_SC_Mode3a.nb

Definitions and Procedures

In[13]:=

```
PoleQpole[H_, s_] := Module[{den, fp, Qp},
    den = Denominator[H];    fp = Sqrt[Coefficient[den, s, 0] / Coefficient[den, s, 2]] / (2 π);
        Qp = (Coefficient[den, s, 2] (2 π fp)) / Coefficient[den, s, 1]; Simplify[{fp, Qp}]];
ZeroQzero[H_, s_] := Module[{fz, num, Qz0},
    num = Numerator[H];        Qz0 = Coefficient[num, s, 2] / Coefficient[num, s, 1];
    fz = Sqrt[Coefficient[num, s, 0] / Coefficient[num, s, 2]] / (2 π);        Simplify[{fz, Qz0 fz}]];
Sensitivity[F_, x_] := (x ∂x F) / F;
GSP[F_, A_] := Simplify[Limit[A Sensitivity[F, A], A → ∞]];
PrintLabeledList[expressions_List, labels_List] := (
    Print[#1[[1]], " = ", #1[[2]]] &) /@ Transpose[{labels, expressions}];
```

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CAF_SC_Mode3a.nb *

Poles, Zeros, Q - factors

```
In[18]:= {fp, Qp} = Simplify[PoleQpole[H, s]];
         PrintLabeledList[{fp, Qp}, {"fp", "Qp"}];
```

$$fp = \frac{\sqrt{\frac{A\,k^2\,R1\,R2\,R3}{R2\,R3\,R4 + R1\,((1+A)\,R3\,R4 + R2\,(R3+R4))}}}{2\,\pi}$$

$$Qp = \frac{k\,R3}{R4\,\sqrt{\frac{A\,k^2\,R1\,R2\,R3}{R2\,R3\,R4 + R1\,((1+A)\,R3\,R4 + R2\,(R3+R4))}}}$$

```
In[20]:= fp0 = Limit[fp, A → ∞];
         Qp0 = Simplify[Limit[Qp, A → ∞] /. k → 1];
         PrintLabeledList[{fp0, Qp0}, {"fp", "Qp"}];
```

$$fp = \frac{\sqrt{\frac{k^2\,R2}{R4}}}{2\,\pi}$$

$$Qp = \frac{R3\,\sqrt{\frac{R2}{R4}}}{R2}$$

```
In[23]:= {fz, Qz} = Simplify[ZeroQzero[H, s]];
         PrintLabeledList[{fz, Qz}, {"fz", "Qz"}];
```

$$fz = \frac{\sqrt{\frac{k^2\,Rh}{R1}}}{2\,\pi}$$

Qz = ComplexInfinity

125%

Određivanje polova, nula, Q faktora

Definicija osetljivosti

CAF_SC_Mode3a.nb *

Gain - Sensitivity Product (GSP)

```
In[25]:= GSPfp = GSP[fp, A];
         GSPQp = GSP[Qp, A];
         PrintLabeledList[{GSPfp, GSPQp}, {"GSPfp", "GSPQp"}];
```

$$GSPfp = \frac{1}{2}\left(1 + \frac{R2}{R1} + R2\left(\frac{1}{R3} + \frac{1}{R4}\right)\right)$$

$$GSPQp = \frac{1}{2}\left(-1 - \frac{R2}{R1} - \frac{R2\,(R3 + R4)}{R3\,R4}\right)$$

150%

Sinteza

CAF_SC_Mode3a.nb *

Design

▪ Find Element Values

```
In[28]:= DesignMode3a[K_, Qp_, wp_, wz_, fclk_, P_:100, R1_:R1nom,
      R2_:R2nom, Rh_:Rhnom] := Module[
         {R3, R4, Rl, Rg},
         R4 = R2 (2 π fclk/(P wp))^2;
         R3 = Qp Sqrt[R2 R4]; Rl = Rh (2 π fclk/(P wz))^2;
         Rg = K Rh R1/R2;
         {R1, R2, R3, R4, Rl, Rh, Rg}];
```

150%

Primer sinteze

CAF_SC_Mode3a.nb *

```
In[29]:= {R1, R2, R3, R4, Rl, Rh, Rg} =
    Together[DesignMode3a[K, Q, W, Z, Fc, P, R1n, R2n, Rhn]];
  PrintLabeledList[{R1, R2, R3, R4, Rl, Rh, Rg},
    {"R1", "R2", "R3", "R4", "Rl", "Rh", "Rg"}];
```

$$R1 = R1n$$

$$R2 = R2n$$

$$R3 = 2 \pi Q \sqrt{\frac{Fc^2 \, R2n^2}{P^2 \, W^2}}$$

$$R4 = \frac{4 \, Fc^2 \, \pi^2 \, R2n}{P^2 \, W^2}$$

$$Rl = \frac{4 \, Fc^2 \, \pi^2 \, Rhn}{P^2 \, Z^2}$$

$$Rh = Rhn$$

$$Rg = \frac{K \, R1n \, Rhn}{R2n}$$

150%

Test

CAF_SC_Mode3a.nb *

```
In[31]:= H3atest = Simplify[ExpandAll[Together[Limit[H, A → ∞]] /. {
    Sqrt[x_^2 y_^2 / z_^2] → x y / z, Sqrt[x_^2 y_^2 p_^2 / z_^2] → x y p / z,
    Sqrt[x_^2 y_^2 p_^2 / (z_^2 n_^2)] → x y p / (z n)}]];
num = Numerator[H3atest];
den = Denominator[H3atest];
numlist = CoefficientList[num, s];
denlist = CoefficientList[den, s];
K3at = numlist[[3]] / denlist[[3]];
H3at = (K3at Simplify[num / numlist[[3]]]) / Simplify[den / denlist[[3]]] /. k → 2 π Fc / P
```

Out[37]=

$$\frac{4\,Fc^2\,K\,\pi^2\,Q\,R2n\,(s^2+z^2)}{4\,Fc^2\,\pi^2\,Q\,R2n\,s^2+2\,Fc\,P\,\pi\left(\frac{2\,Fc\,\pi\,Q\,R2n}{P}+2\,\pi\,s\,\sqrt{\frac{Fc^2\,R2n^2}{P^2\,W^2}}\right)W^2}$$

150%

Numerički primer sinteze

CAF_SC_Mode3a.nb *

```
In[38]:= values = N[{K → 1, Q → 1.0349, W → 2 π 1710.9457,
              Z → 2 π 5129.3034, Fc → 256. 10^3,
              P → 100, R12 → 23.16 10^3, R22 → 10. 10^3,
        Rh2 → 238.6 10^3}];
         h1 = N[H /. k → (2 π Fc)/P /. values];
         H3atest = Limit[h1, A → ∞];
         H3atest = H3atest /. Sqrt[x_^2] → x;
         num = Numerator[H3atest];
         den = Denominator[H3atest];
         numlist = CoefficientList[num, s];
         denlist = CoefficientList[den, s];
         K3at = numlist[[3]] / denlist[[3]];
         H3at = (K3at Simplify[num / numlist[[3]]]) / Simplify[den / denlist[[3]]]
```

Out[47]=

$$\frac{1.\ (1.03867 \times 10^{9} + 1.\ s^{2})}{1.15567 \times 10^{8} + 10\,387.7\ s + 1.\ s^{2}}$$

150%

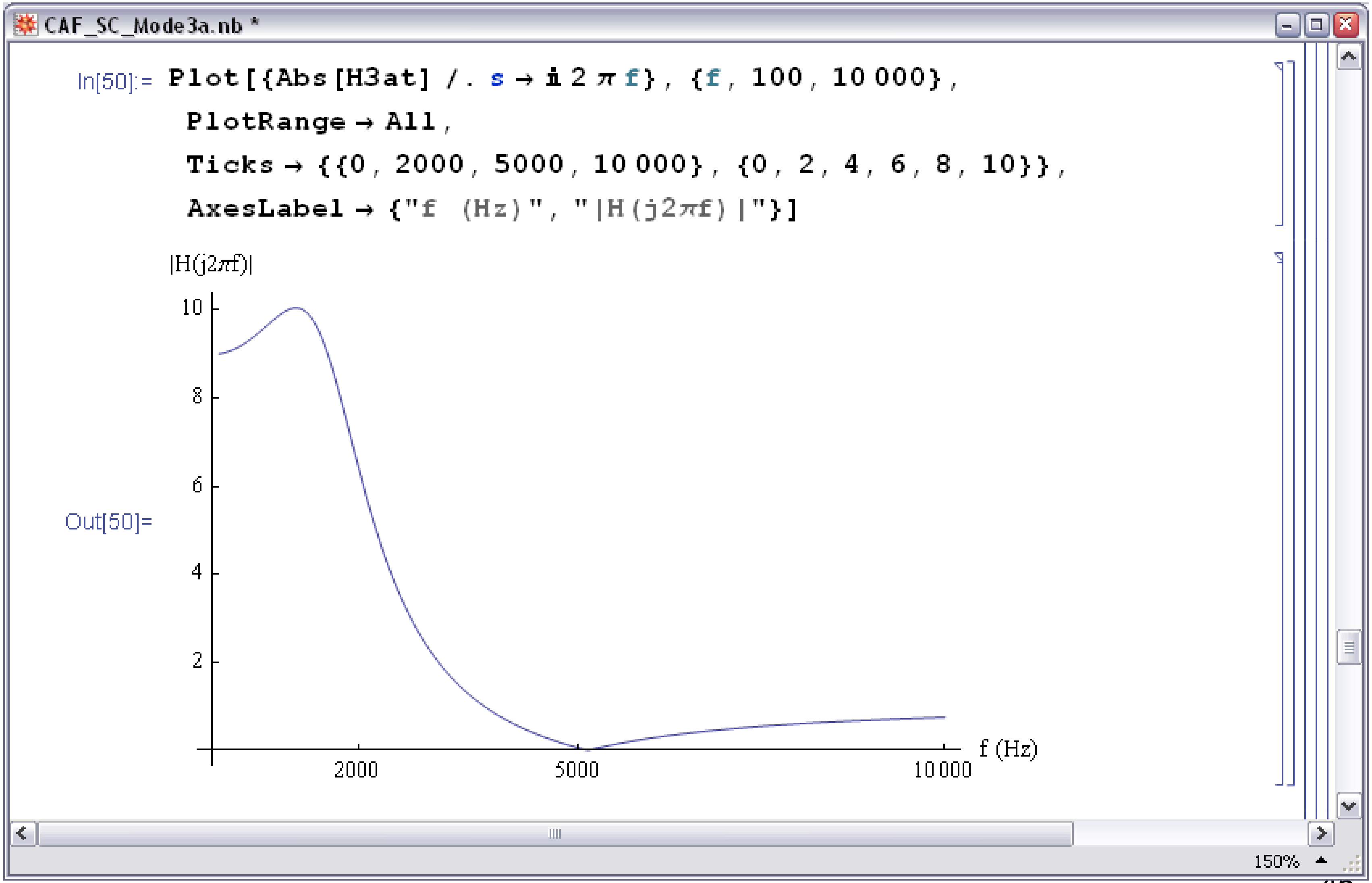
Rezultat sinteze

CAF_SC_Mode3a.nb *

```
In[48]:= Rexample1 = N[{R1, R2, R3, R4, Rl, Rh, Rg} /. values] /.
           √(R2n^2) → R2n;
         PrintLabeledList[Rexample1,
           {"R1", "R2", "R3", "R4", "Rl", "Rh", "Rg"}];

R1 = R1n

R2 = R2n

R3 = 1.54847 R2n

R4 = 2.23876 R2n

Rl = 0.249094 Rhn

Rh = Rhn

Rg = 1. R1n Rhn / R2n
```

150%

Crtanje funkcije prenosa

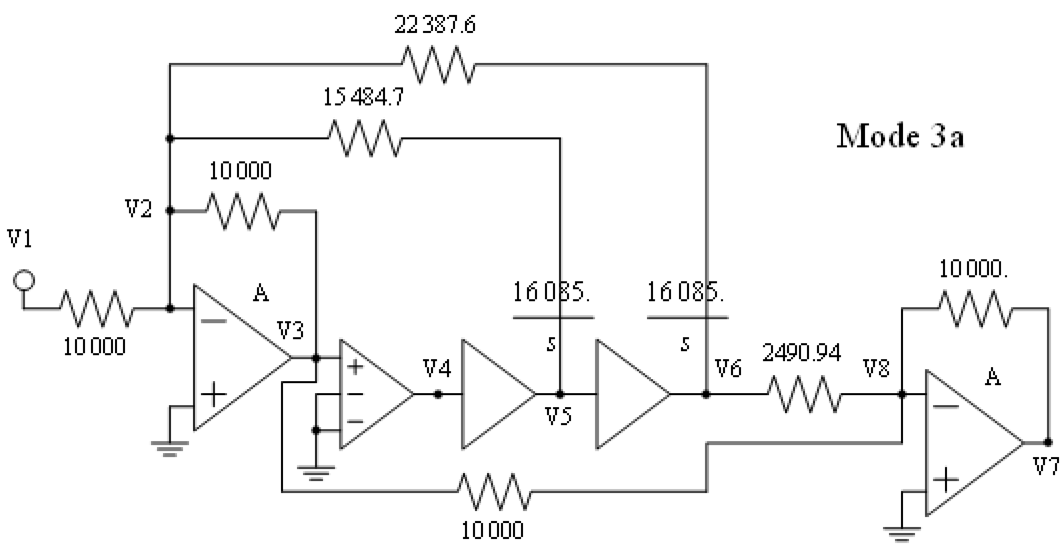


Crtanje šeme

CAF_SC_Mode3a.nb *

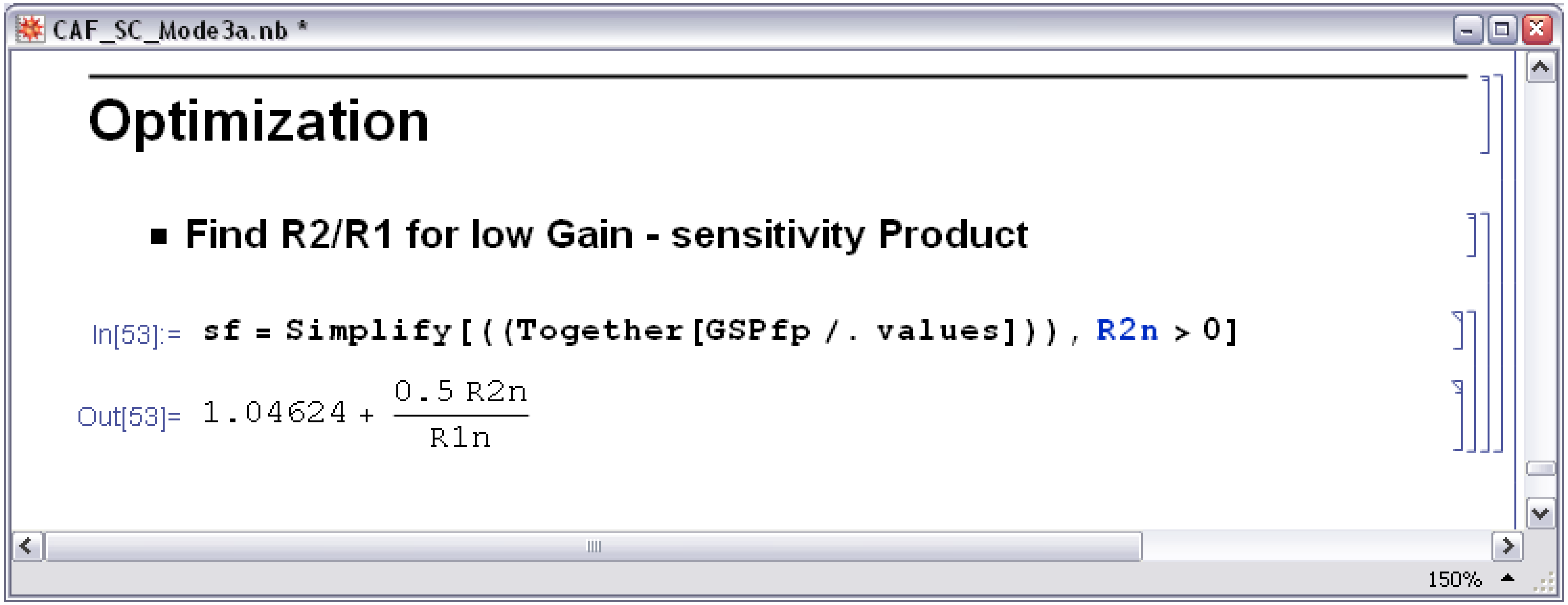
```
In[51]:= rnum = Rexample1 /. {R1n → 10^4, R2n → 10^4, Rhn → 10^4}

Out[51]= {10 000, 10 000, 15 484.7, 22 387.6, 2490.94, 10 000, 10 000.}

In[52]:= DrawMode3a[0, 0, 1/2, 5/4, 8] /. {"R1" → rnum[[1]], "R2" → rnum[[2]],
    "R3" → rnum[[3]], "R4" → rnum[[4]], "R1" → rnum[[5]],
    "Rh" → rnum[[6]], "Rg" → rnum[[7]], "k/s" → (2 π Fc)/(P s) /. values}
```

Out[52]=

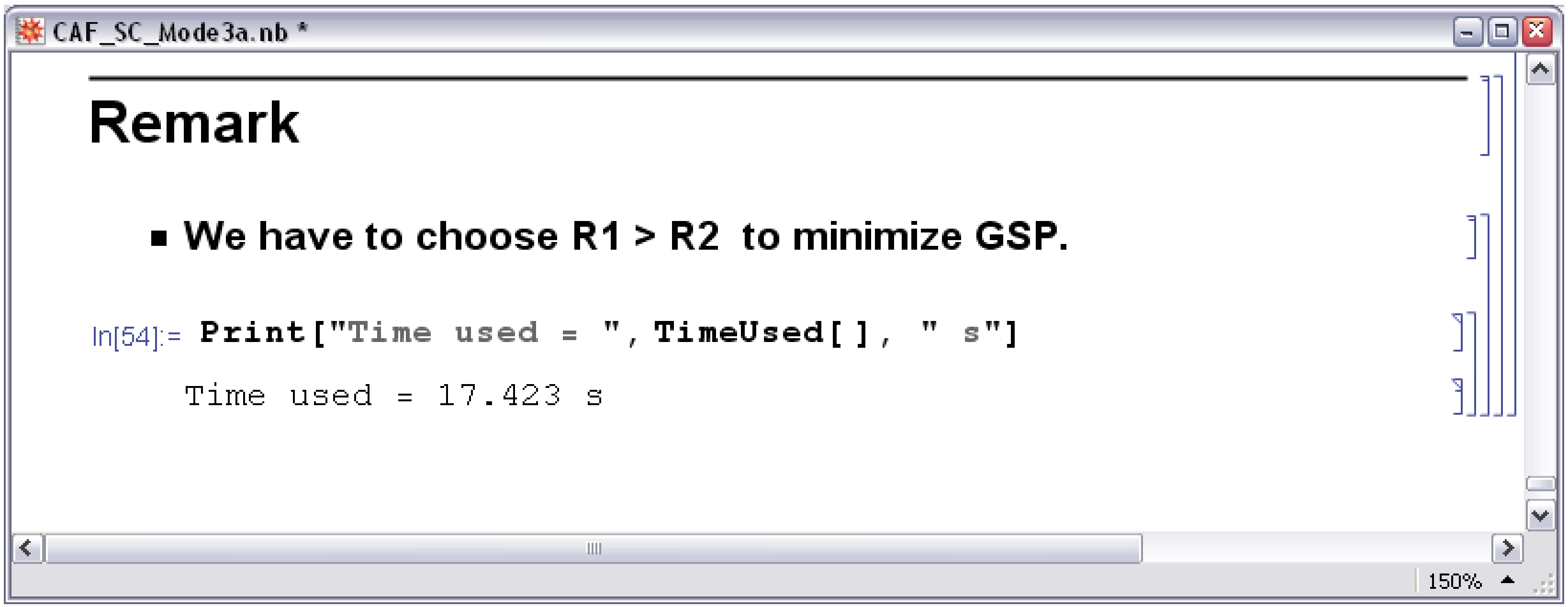


150%

Optimizacija



Komentar



CAF_SC_Mode3a.nb *

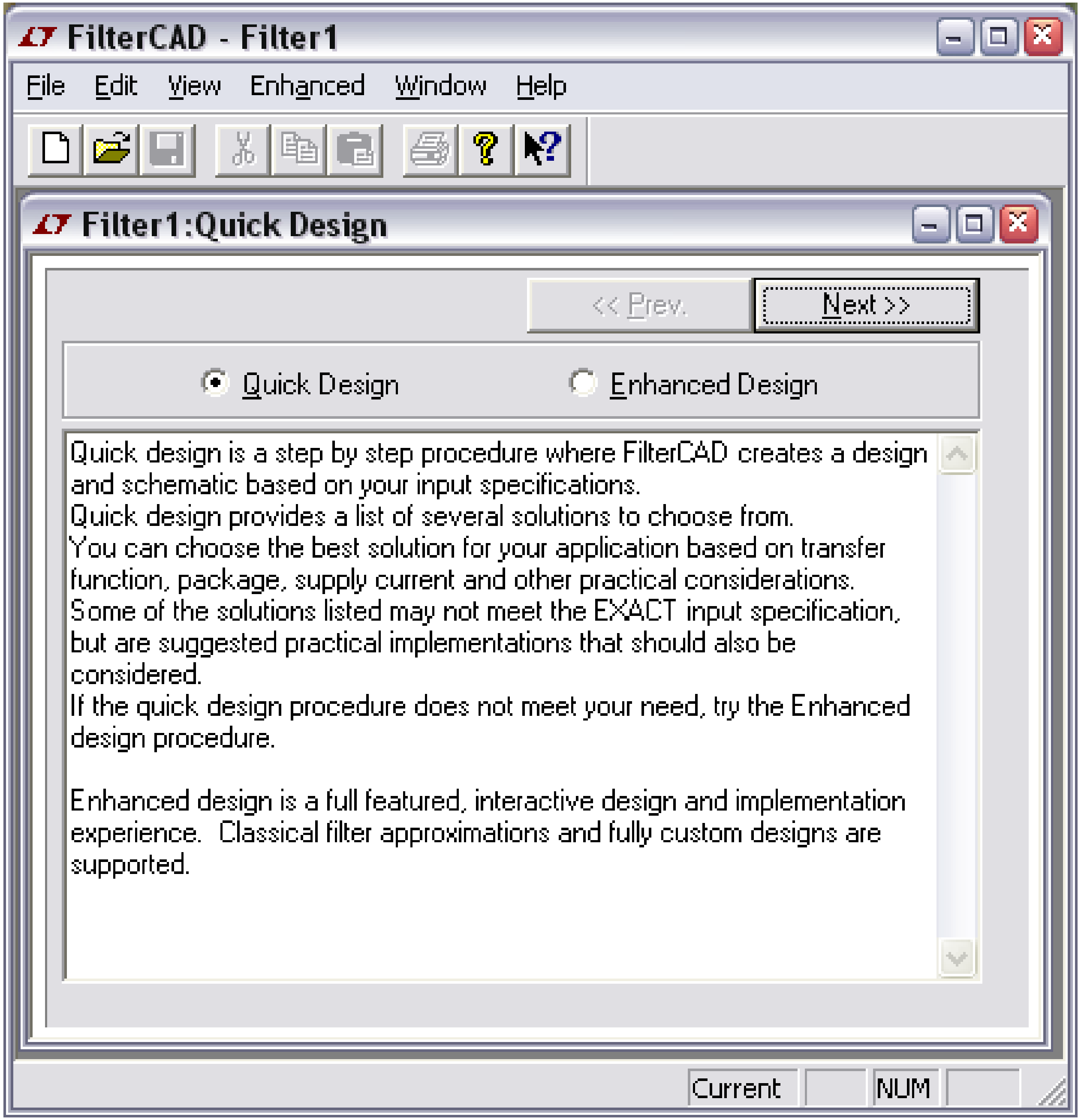
Remark

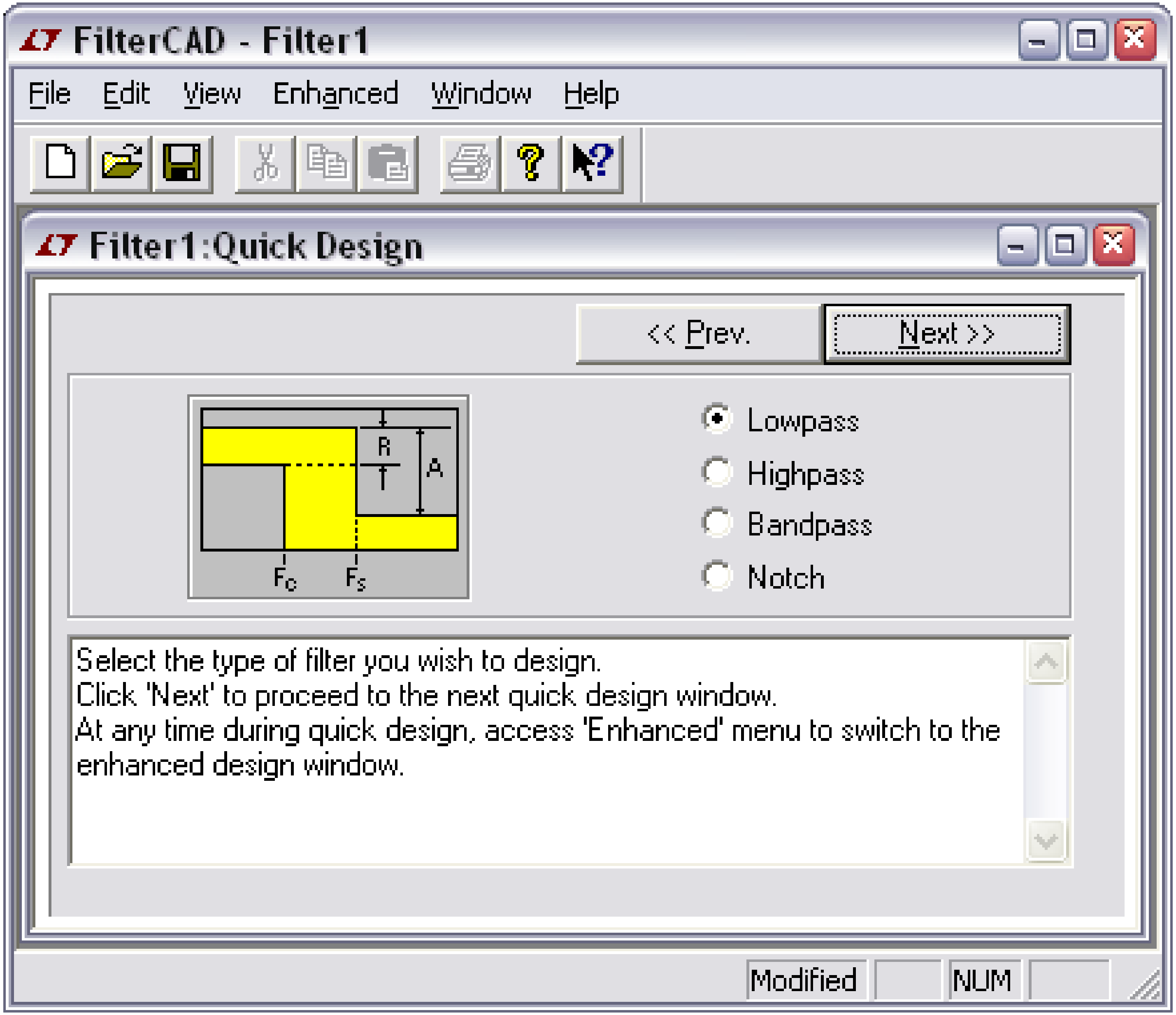
- **We have to choose R1 > R2 to minimize GSP.**

In[54]:=
```
Print["Time used = ", TimeUsed[ ], " s"]
```

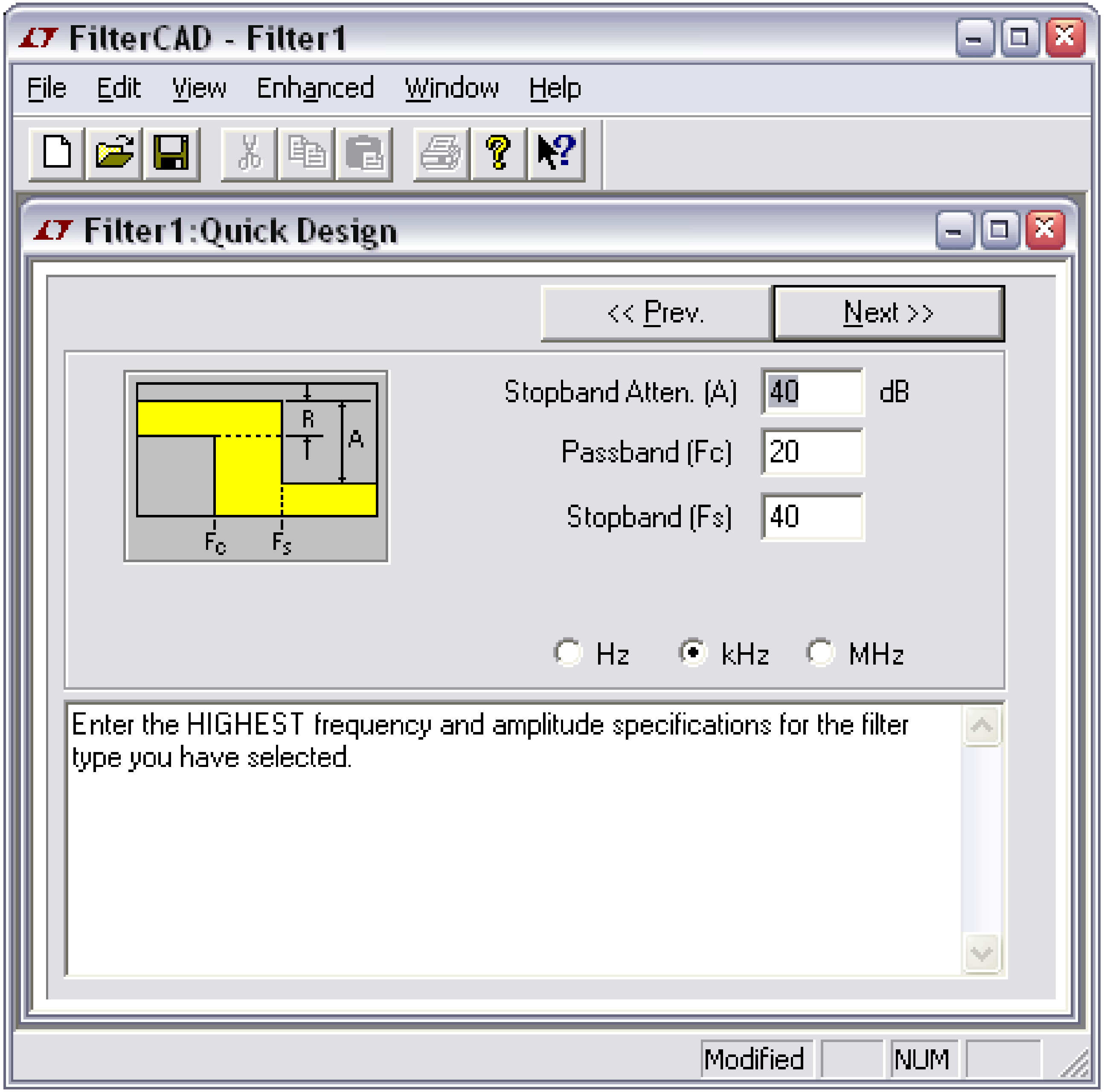
```
Time used = 17.423 s
```

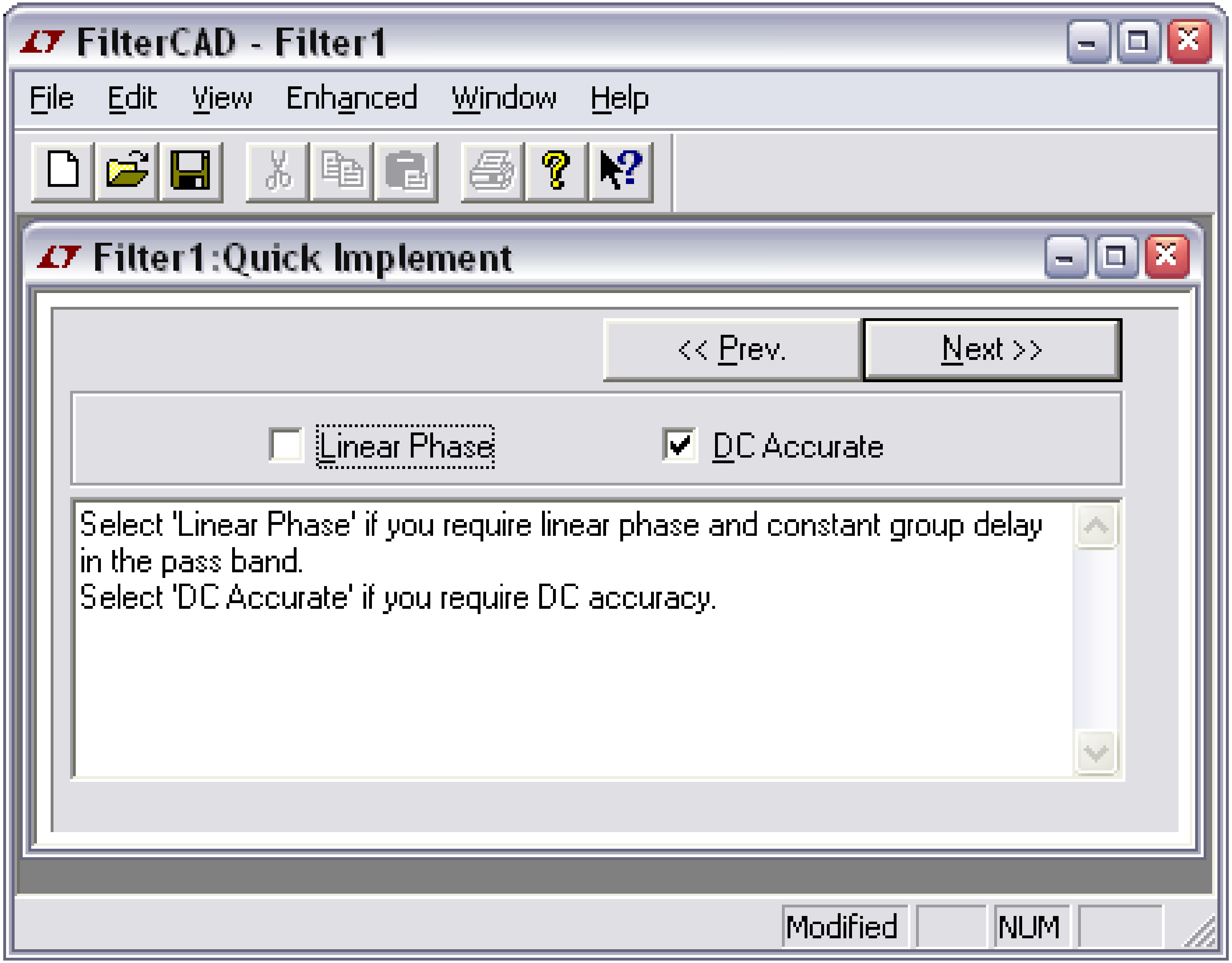
150%

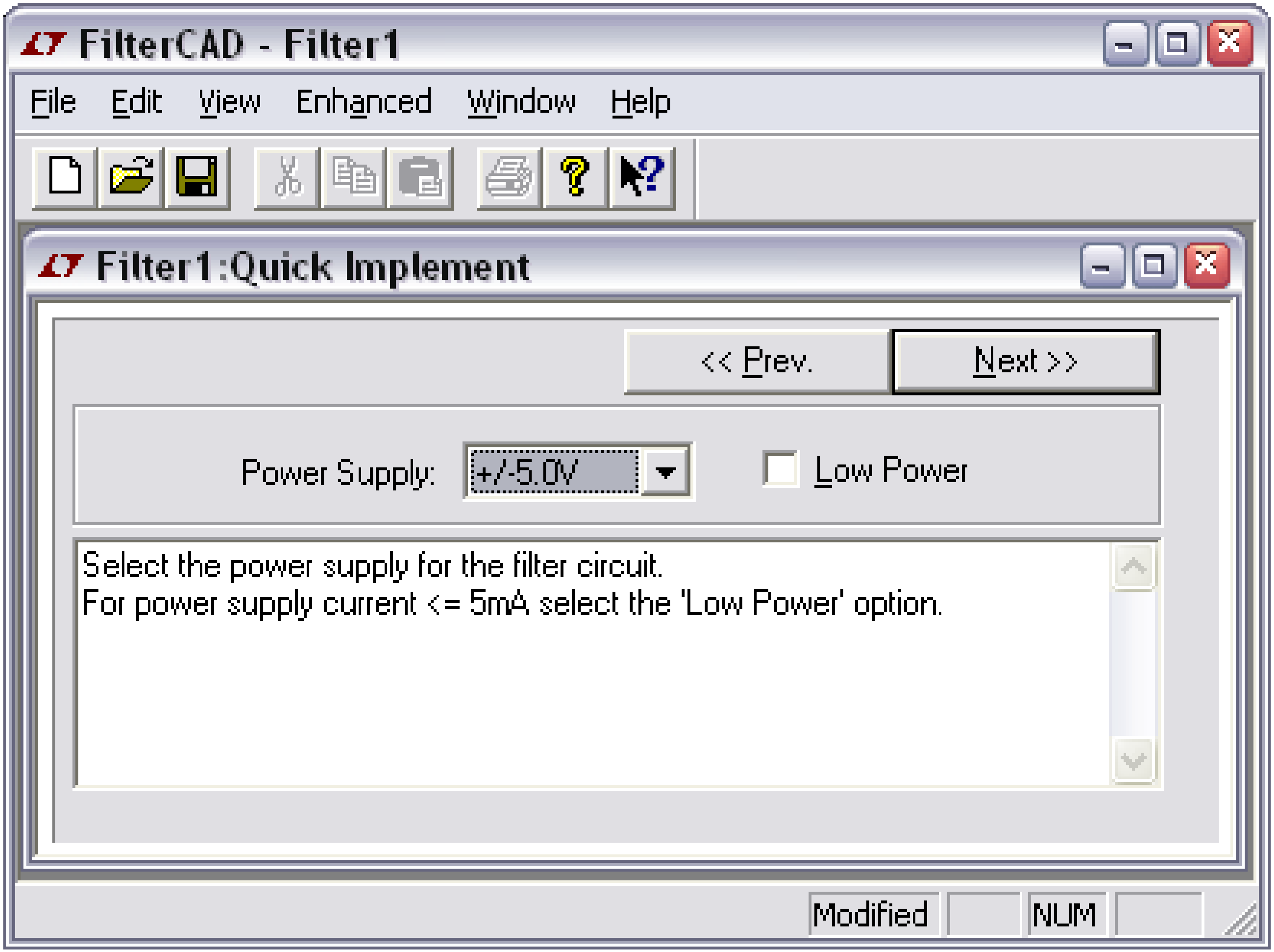

FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Design
<< Prev.
Next >>
Quick Design
Enhanced Design
Quick design is a step by step procedure where FilterCAD creates a design and schematic based on your input specifications.
Quick design provides a list of several solutions to choose from.
You can choose the best solution for your application based on transfer function, package, supply current and other practical considerations.
Some of the solutions listed may not meet the EXACT input specification, but are suggested practical implementations that should also be considered.
If the quick design procedure does not meet your need, try the Enhanced design procedure.
Enhanced design is a full featured, interactive design and implementation experience. Classical filter approximations and fully custom designs are supported.
Current
NUM



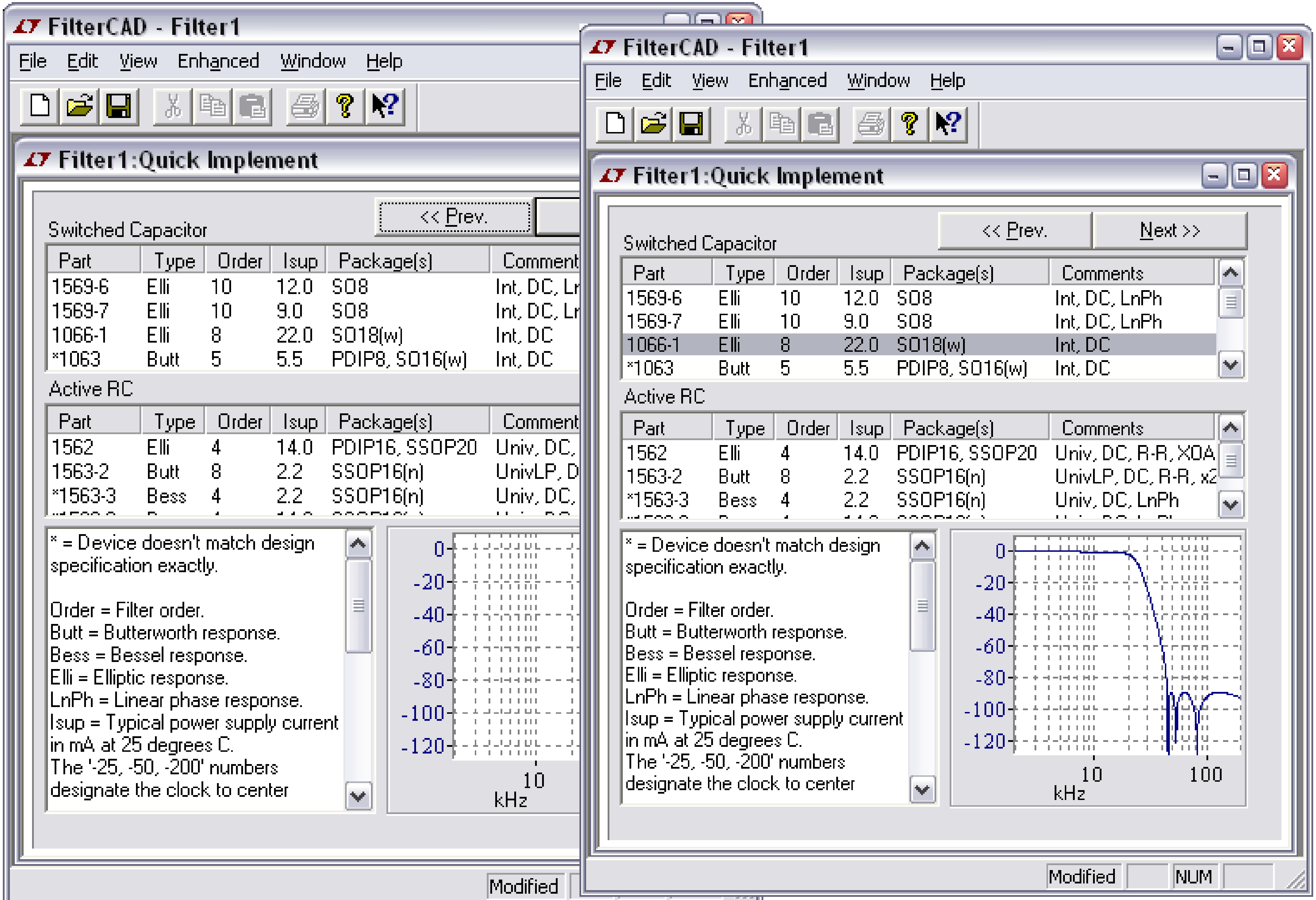
FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Design
<< Prev.
Next >>
R
A
Fc
Fs
Lowpass
Highpass
Bandpass
Notch
Select the type of filter you wish to design.
Click 'Next' to proceed to the next quick design window.
At any time during quick design, access 'Enhanced' menu to switch to the enhanced design window.
Modified
NUM

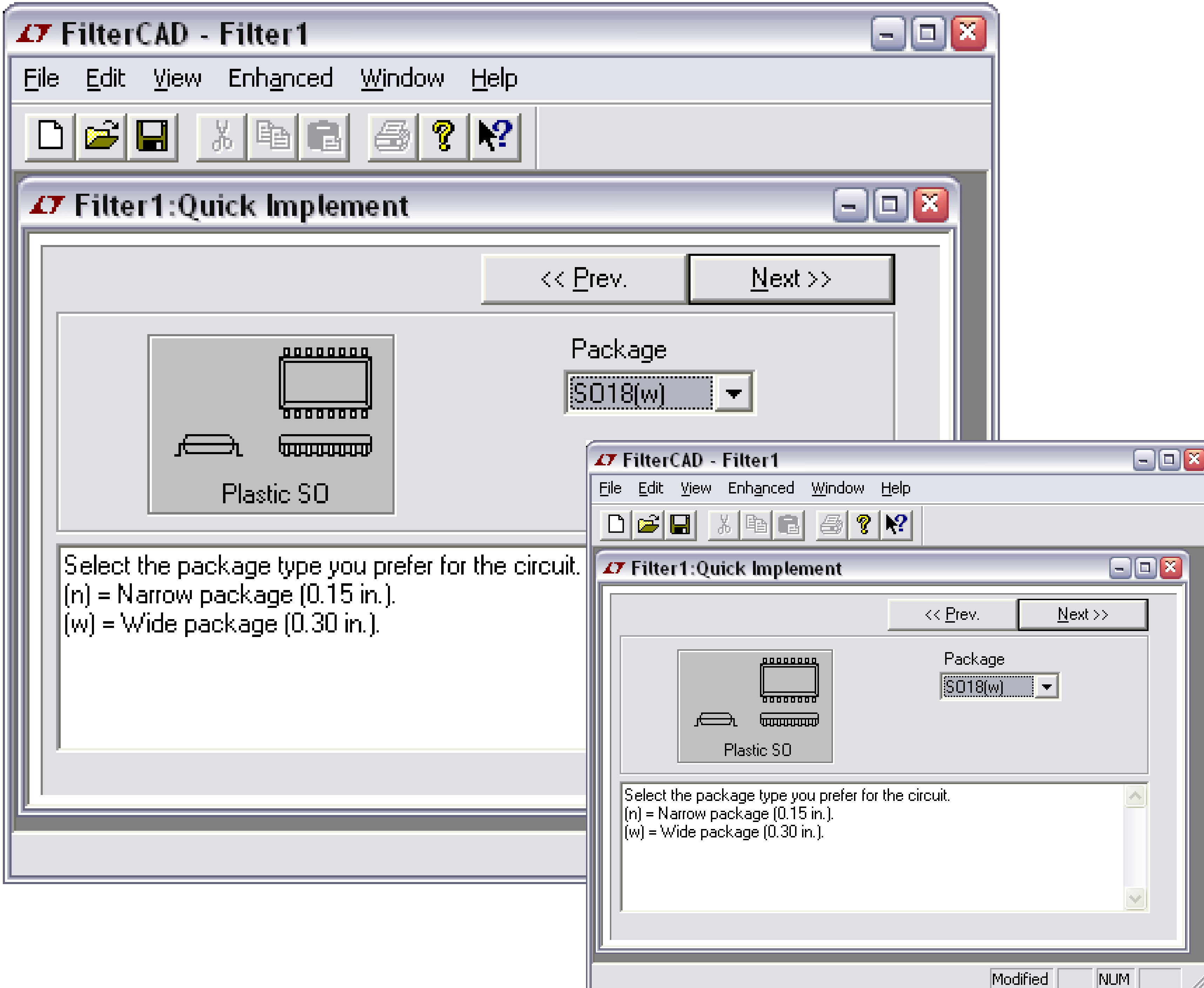

FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Design
<< Prev.
Next >>
R
A
Fc
Fs
Stopband Atten. (A) 40 dB
Passband (Fc) 20
Stopband (Fs) 40
Hz
kHz
MHz
Enter the HIGHEST frequency and amplitude specifications for the filter type you have selected.
Modified
NUM

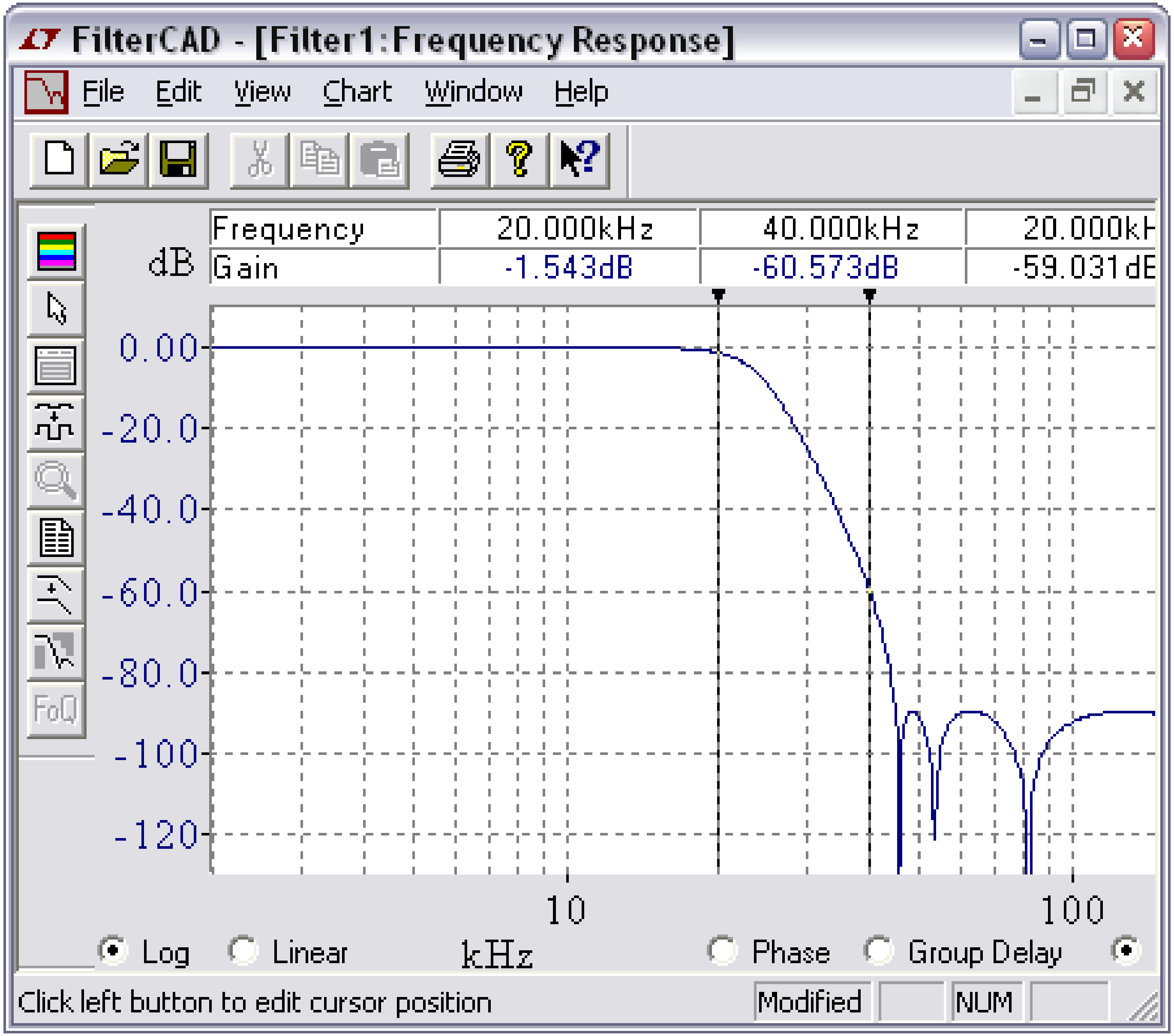

FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Implement
<< Prev.
Next >>
Linear Phase
DC Accurate
Select 'Linear Phase' if you require linear phase and constant group delay in the pass band.
Select 'DC Accurate' if you require DC accuracy.
Modified
NUM

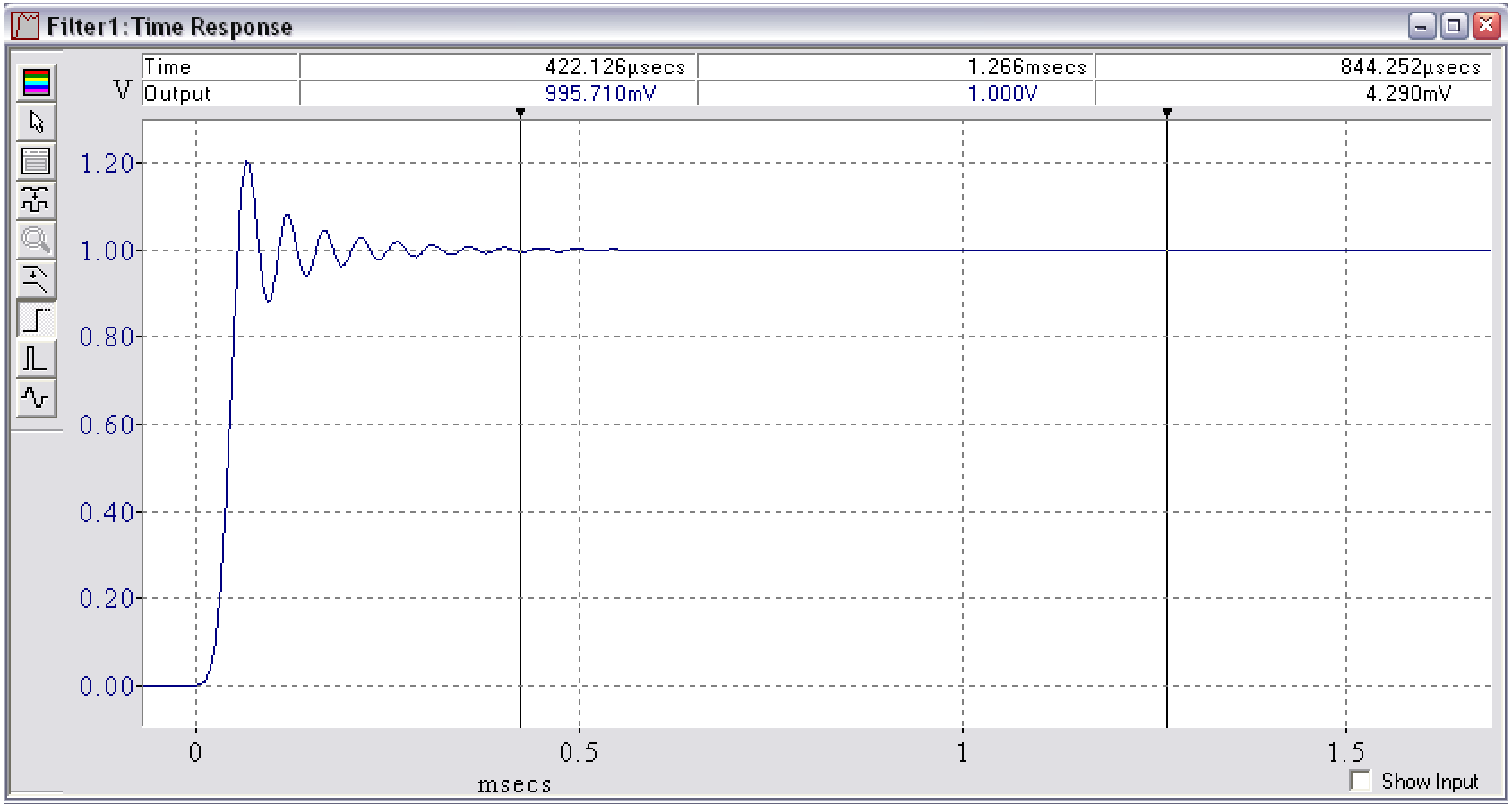


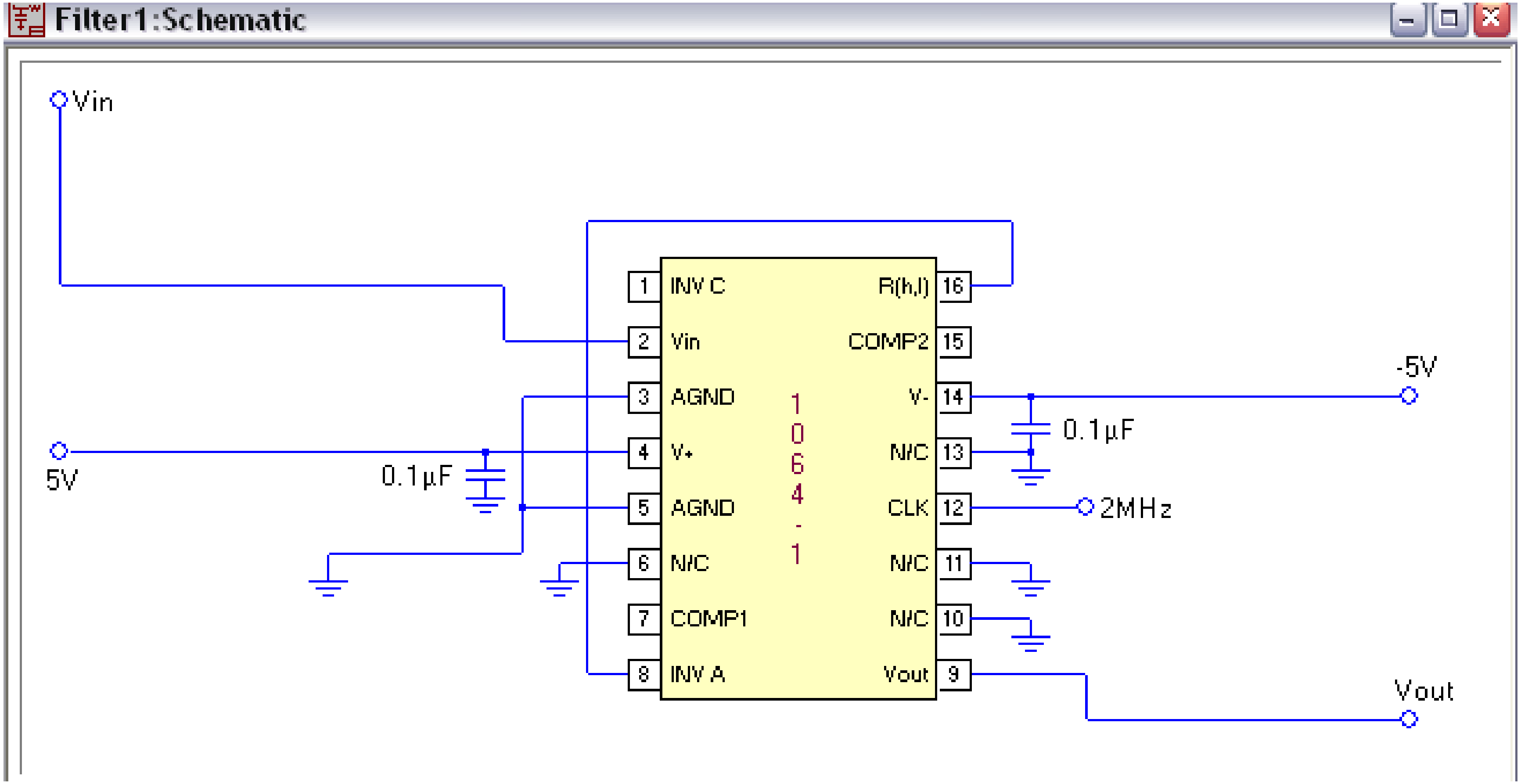
FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Implement
<< Prev.
Next >>
Power Supply:
+/-5.0V
Low Power
Select the power supply for the filter circuit.
For power supply current <= 5mA select the 'Low Power' option.
Modified
NUM

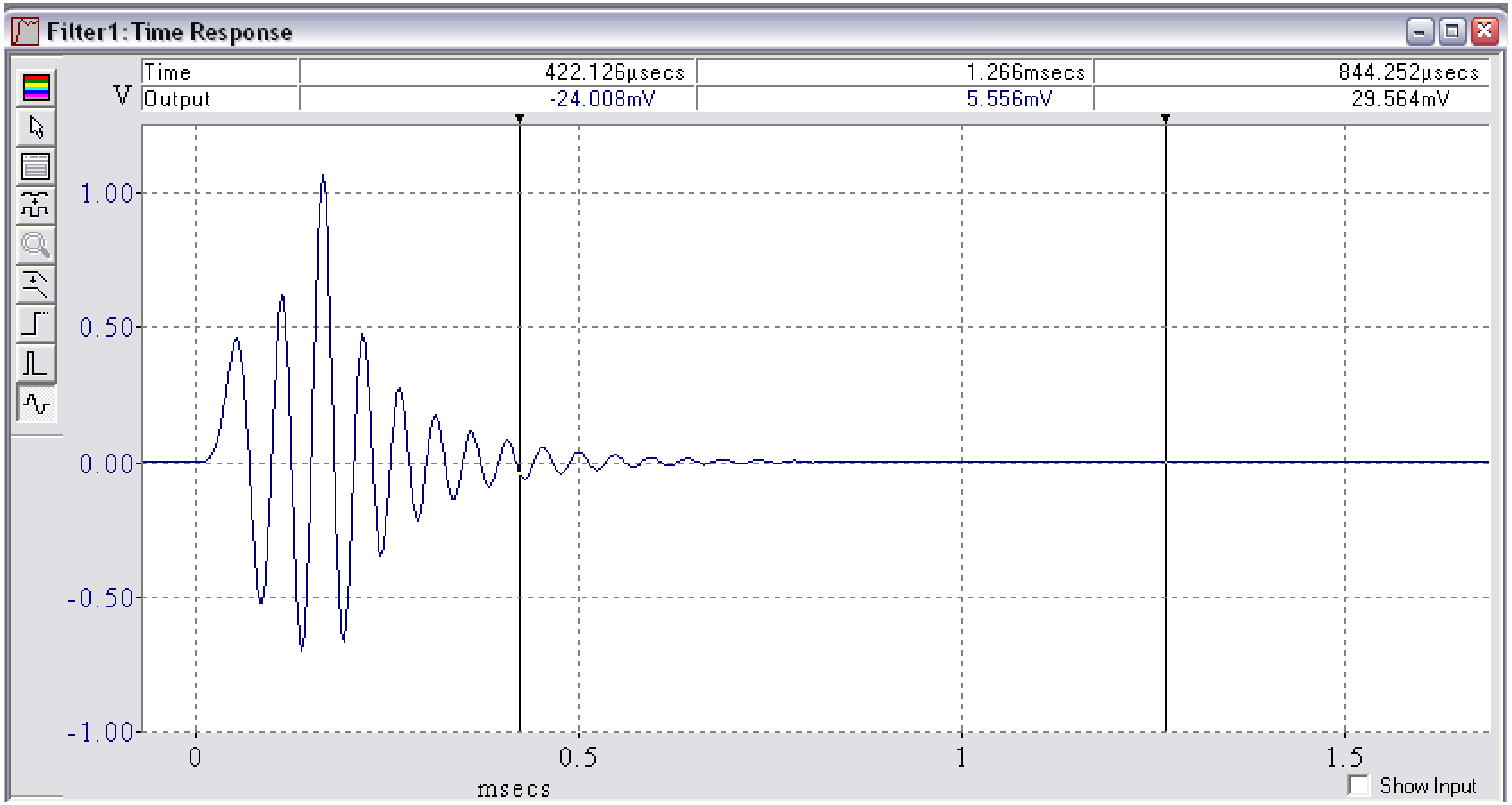

FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Implement
<< Prev.
Next >>
Switched Capacitor
Part Type Order Isup Package(s) Comments
1569-6 Elli 10 12.0 SO8 Int, DC, LnPh
1569-7 Elli 10 9.0 SO8 Int, DC, LnPh
1066-1 Elli 8 22.0 SO18(w) Int, DC
*1063 Butt 5 5.5 PDIP8, SO16(w) Int, DC
Active RC
Part Type Order Isup Package(s) Comments
1562 Elli 4 14.0 PDIP16, SSOP20 Univ, DC, R-R, XOA
1563-2 Butt 8 2.2 SSOP16(n) UnivLP, DC, R-R, x2
*1563-3 Bess 4 2.2 SSOP16(n) Univ, DC, LnPh
* = Device doesn't match design specification exactly.
Order = Filter order.
Butt = Butterworth response.
Bess = Bessel response.
Elli = Elliptic response.
LnPh = Linear phase response.
Isup = Typical power supply current in mA at 25 degrees C.
The '-25, -50, -200' numbers designate the clock to center
0
-20
-40
-60
-80
-100
-120
10
100
kHz
Modified
NUM


FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Implement
<< Prev.
Next >>
Package
SO18(w)
Plastic SO
Select the package type you prefer for the circuit.
(n) = Narrow package (0.15 in.).
(w) = Wide package (0.30 in.).
Modified
NUM

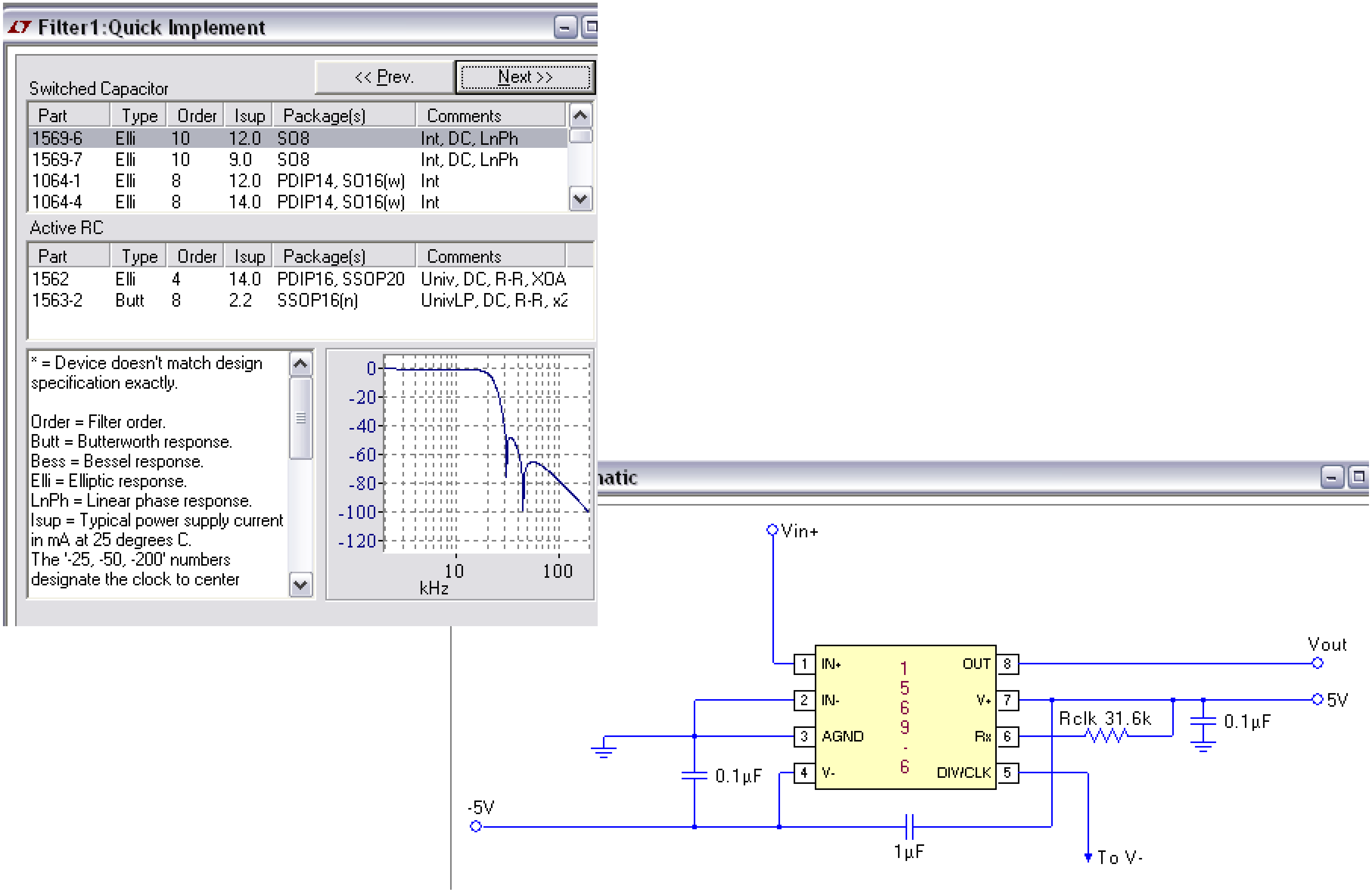

FilterCAD - [Filter1:Frequency Response]
File Edit View Chart Window Help
Frequency 20.000kHz 40.000kHz 20.000kH
dB Gain -1.543dB -60.573dB -59.031dE
0.00
-20.0
-40.0
-60.0
-80.0
-100
-120
10
100
kHz
Log
Linear
Phase
Group Delay
Click left button to edit cursor position
Modified
NUM

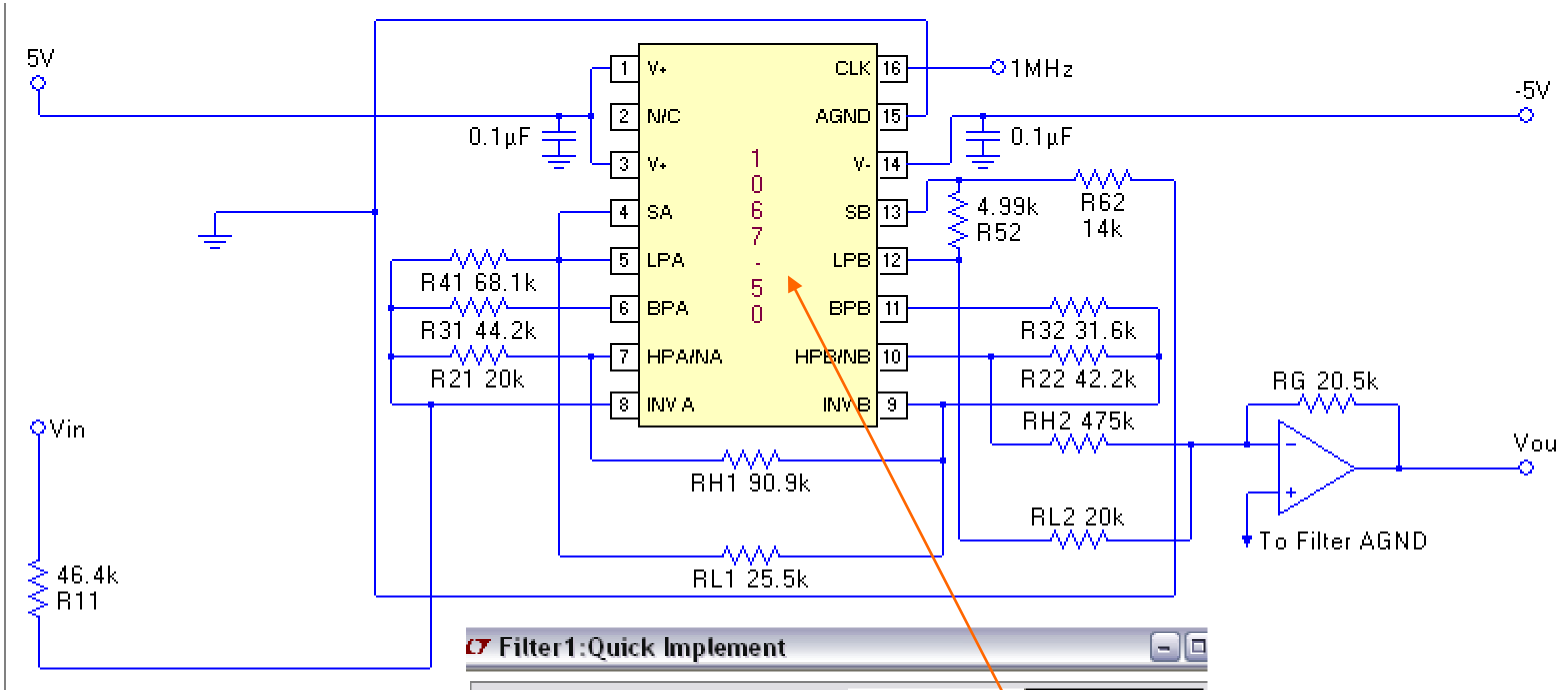

Filter1:Time Response
Time
422.126µsecs
1.266msecs
844.252µsecs
V
Output
995.710mV
1.000V
4.290mV
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
0.5
1
1.5
msecs
Show Input

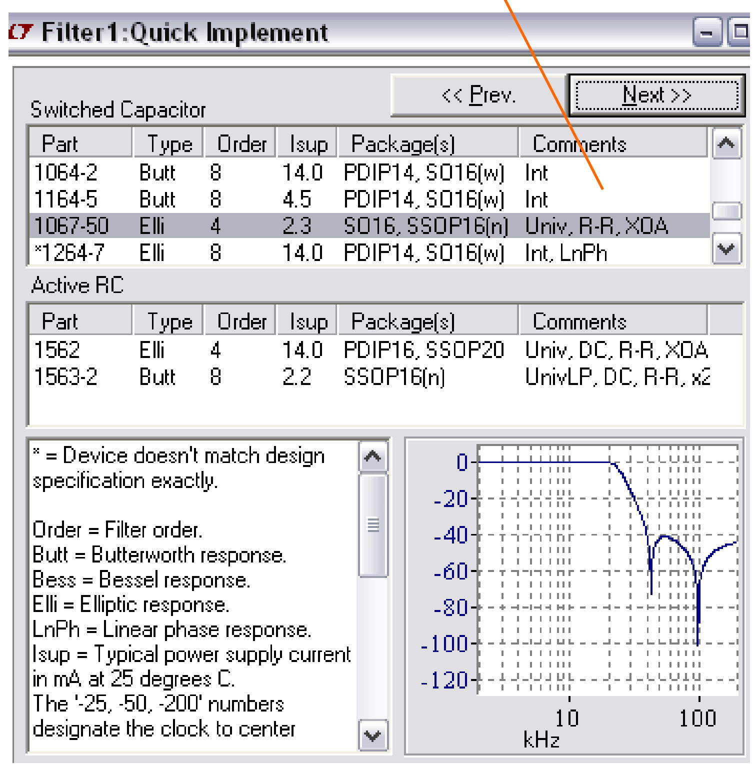

Filter1:Schematic
Vin
5V
0.1µF
INV C
Vin
AGND
V+
AGND
N/C
COMP1
INV A
R(h,l)
COMP2
V-
N/C
CLK
N/C
N/C
Vout
1
2
3
4
5
6
7
8
16
15
14
13
12
11
10
9
1064-1
-5V
0.1µF
2MHz
Vout



Filter1:Time Response
Time
422.126µsecs
1.266msecs
844.252µsecs
V
Output
-24.008mV
5.556mV
29.564mV
1.00
0.50
0.00
-0.50
-1.00
0
0.5
1
1.5
msecs
Show Input


Filter1:Quick Implement
<< Prev.
Next >>
Switched Capacitor
Part | Type | Order | Isup | Package(s) | Comments
1569-6 | Elli | 10 | 12.0 | SO8 | Int, DC, LnPh
1569-7 | Elli | 10 | 9.0 | SO8 | Int, DC, LnPh
1064-1 | Elli | 8 | 12.0 | PDIP14, SO16(w) | Int
1064-4 | Elli | 8 | 14.0 | PDIP14, SO16(w) | Int
Active RC
Part | Type | Order | Isup | Package(s) | Comments
1562 | Elli | 4 | 14.0 | PDIP16, SSOP20 | Univ, DC, R-R, XOA
1563-2 | Butt | 8 | 2.2 | SSOP16(n) | UnivLP, DC, R-R, x2
* = Device doesn't match design specification exactly.
Order = Filter order.
Butt = Butterworth response.
Bess = Bessel response.
Elli = Elliptic response.
LnPh = Linear phase response.
Isup = Typical power supply current in mA at 25 degrees C.
The '-25, -50, -200' numbers designate the clock to center
0
-20
-40
-60
-80
-100
-120
10
100
kHz
atic
Vin+
Vout
5V
-5V
IN+
IN-
AGND
V-
OUT
V+
Rx
DIV/CLK
1569-6
Rclk 31.6k
0.1µF
0.1µF
1µF
To V-

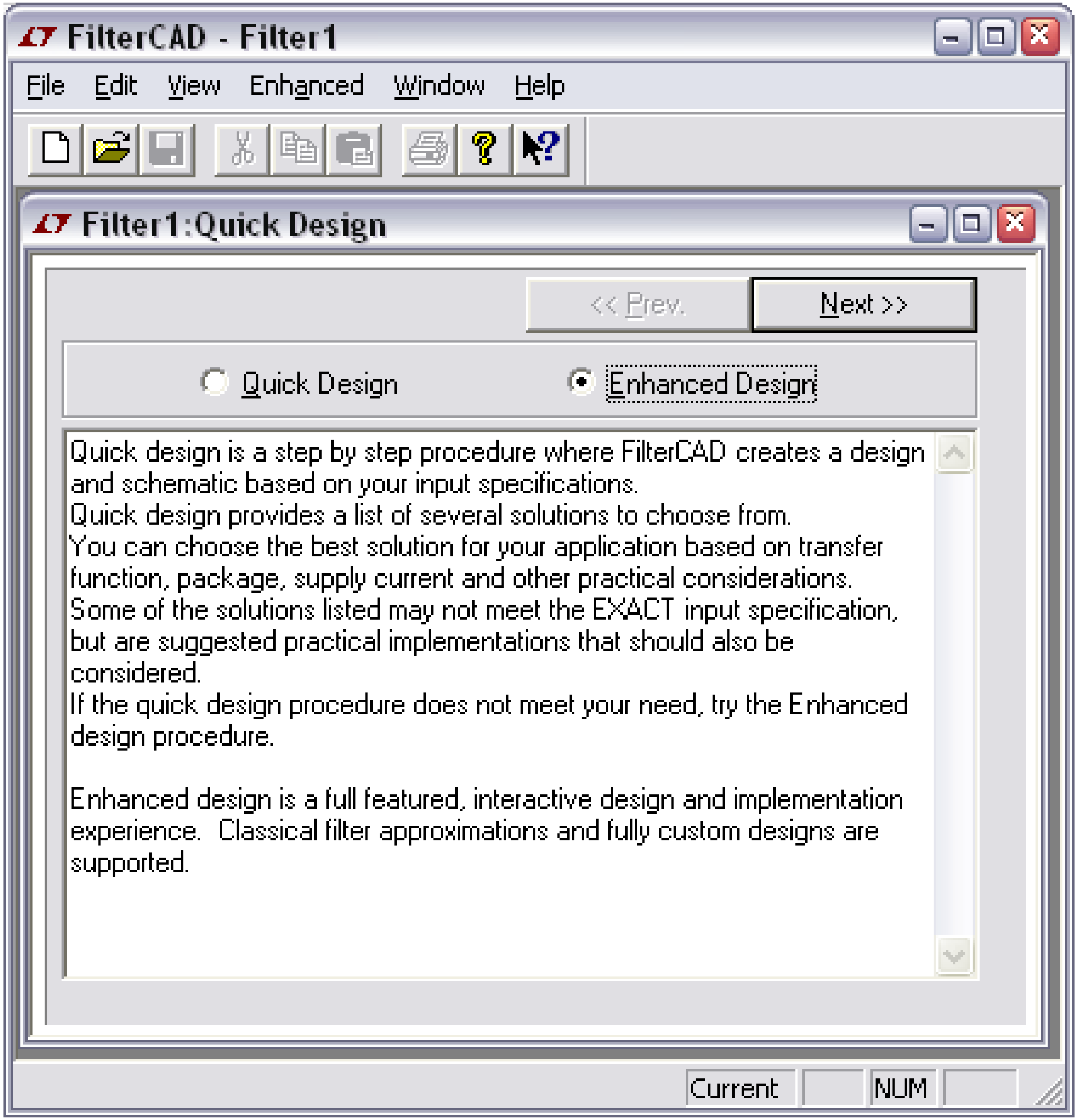




Part	Type	Order	Isup	Package(s)	Comments
1064-2	Butt	8	14.0	PDIP14, SO16(w)	Int
1164-5	Butt	8	4.5	PDIP14, SO16(w)	Int
1067-50	Elli	4	2.3	SO16, SSOP16(n)	Univ, R-R, XOA
*1264-7	Elli	8	14.0	PDIP14, SO16(w)	Int, LnPh

Active RC

Part	Type	Order	Isup	Package(s)	Comments
1562	Elli	4	14.0	PDIP16, SSOP20	Univ, DC, R-R, XOA
1563-2	Butt	8	2.2	SSOP16(n)	UnivLP, DC, R-R, x2


FilterCAD - Filter1
File Edit View Enhanced Window Help
Filter1:Quick Design
<< Prev.
Next >>
Quick Design
Enhanced Design
Quick design is a step by step procedure where FilterCAD creates a design and schematic based on your input specifications.
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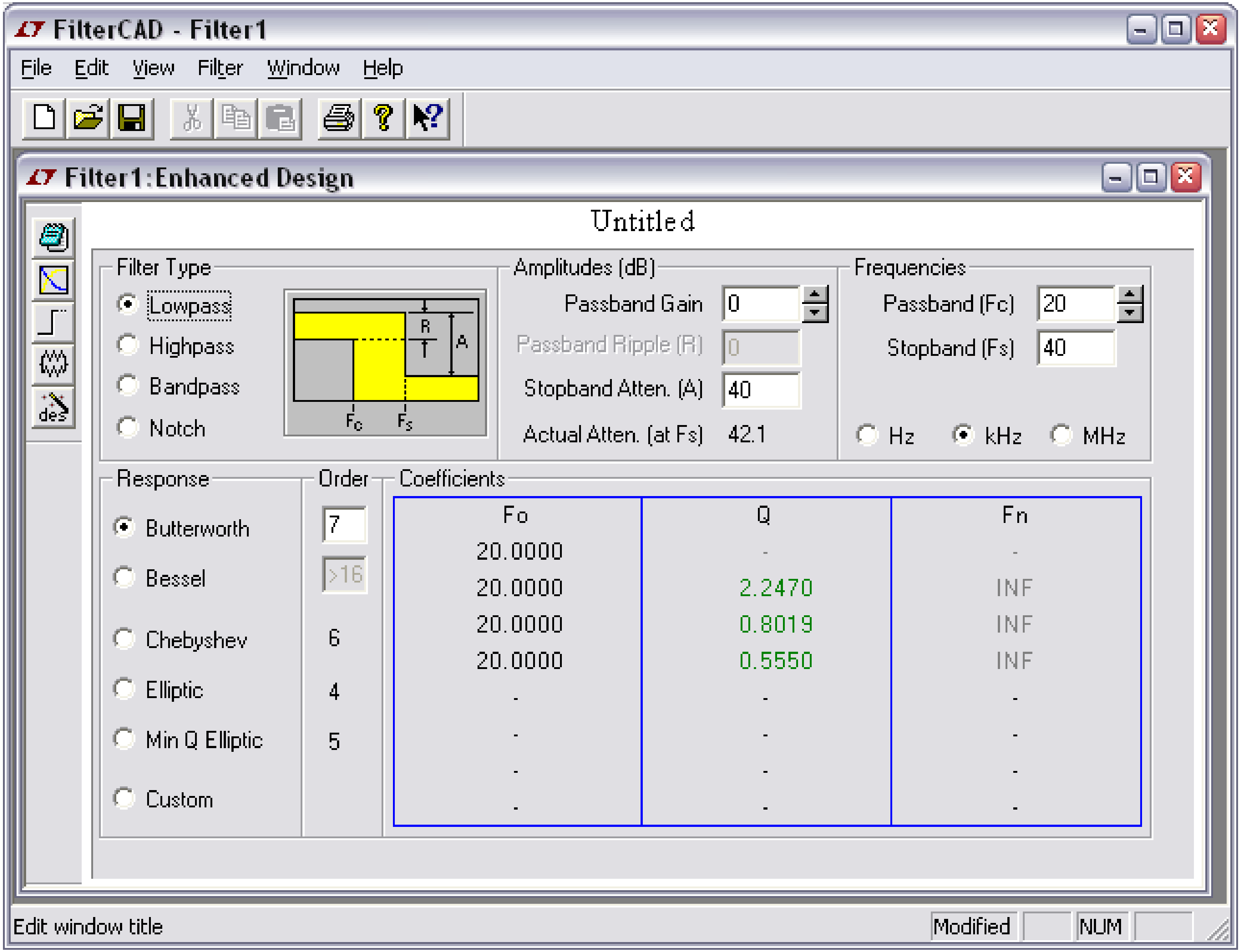
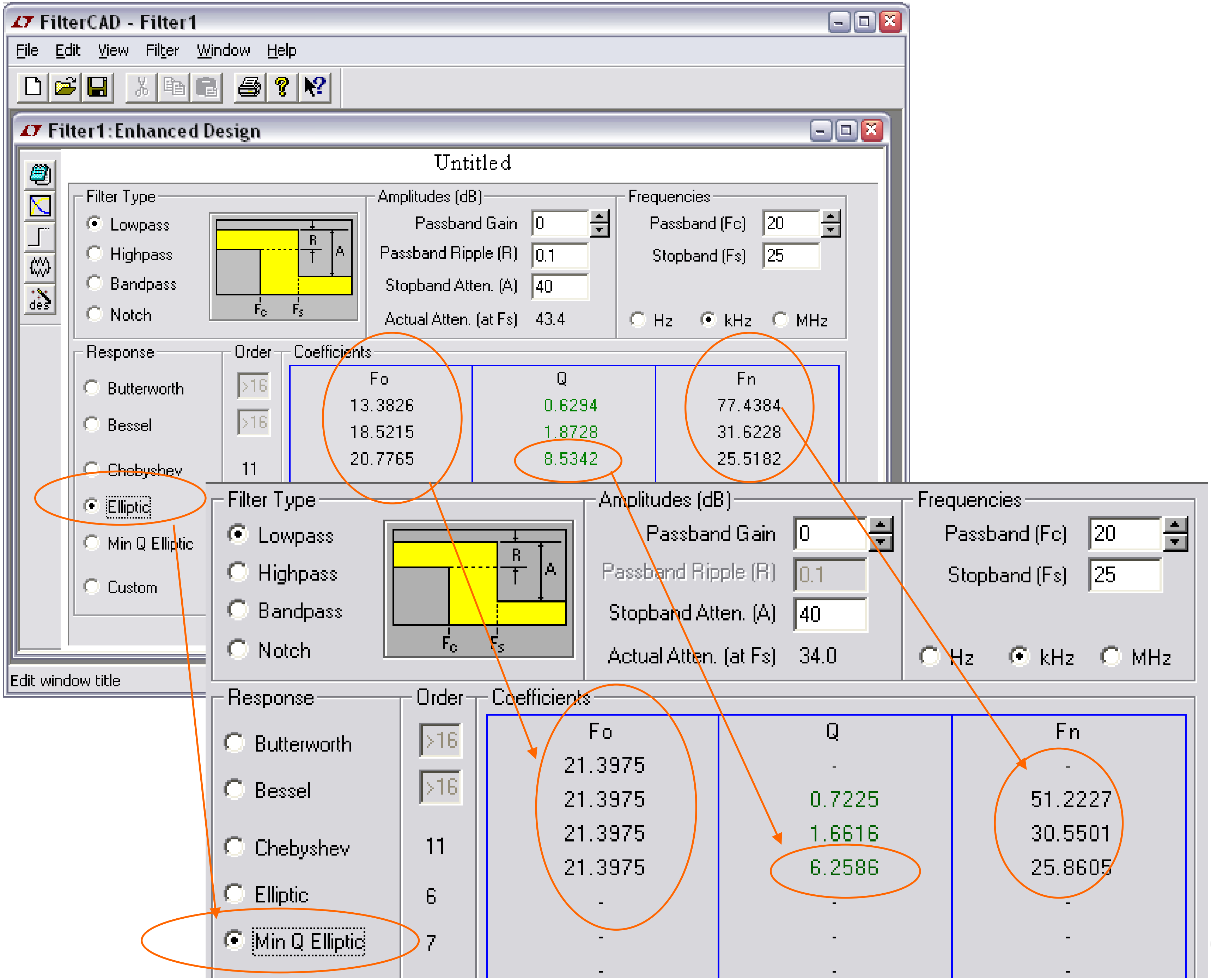
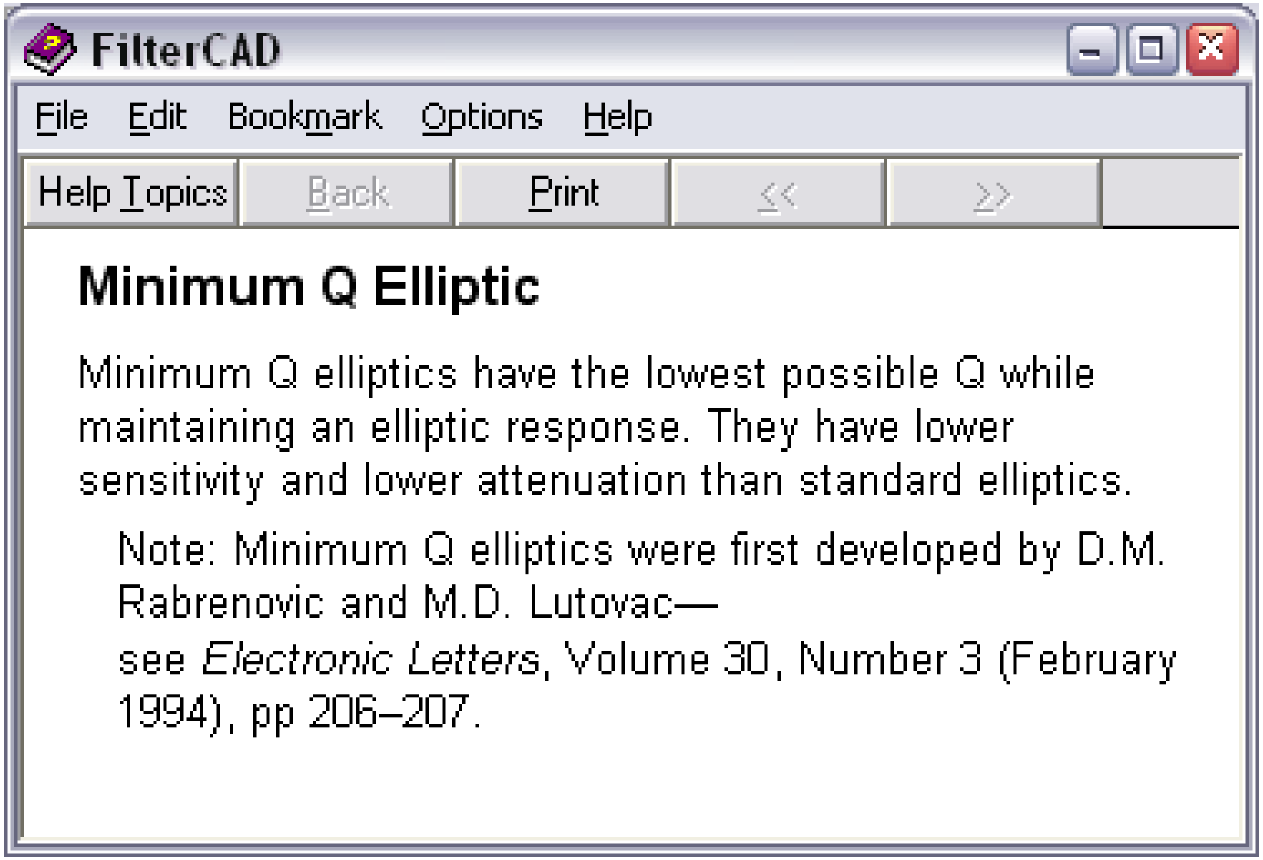
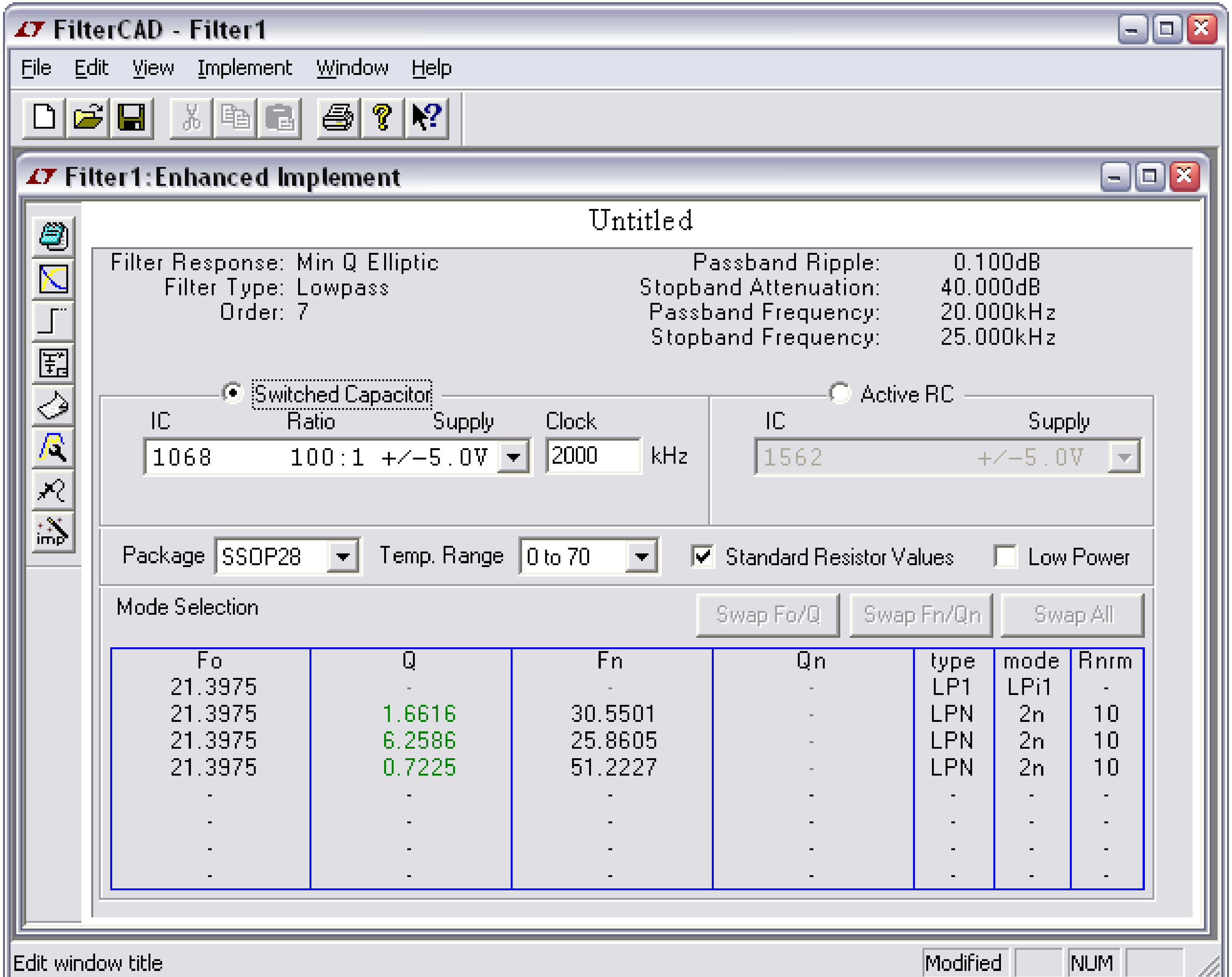
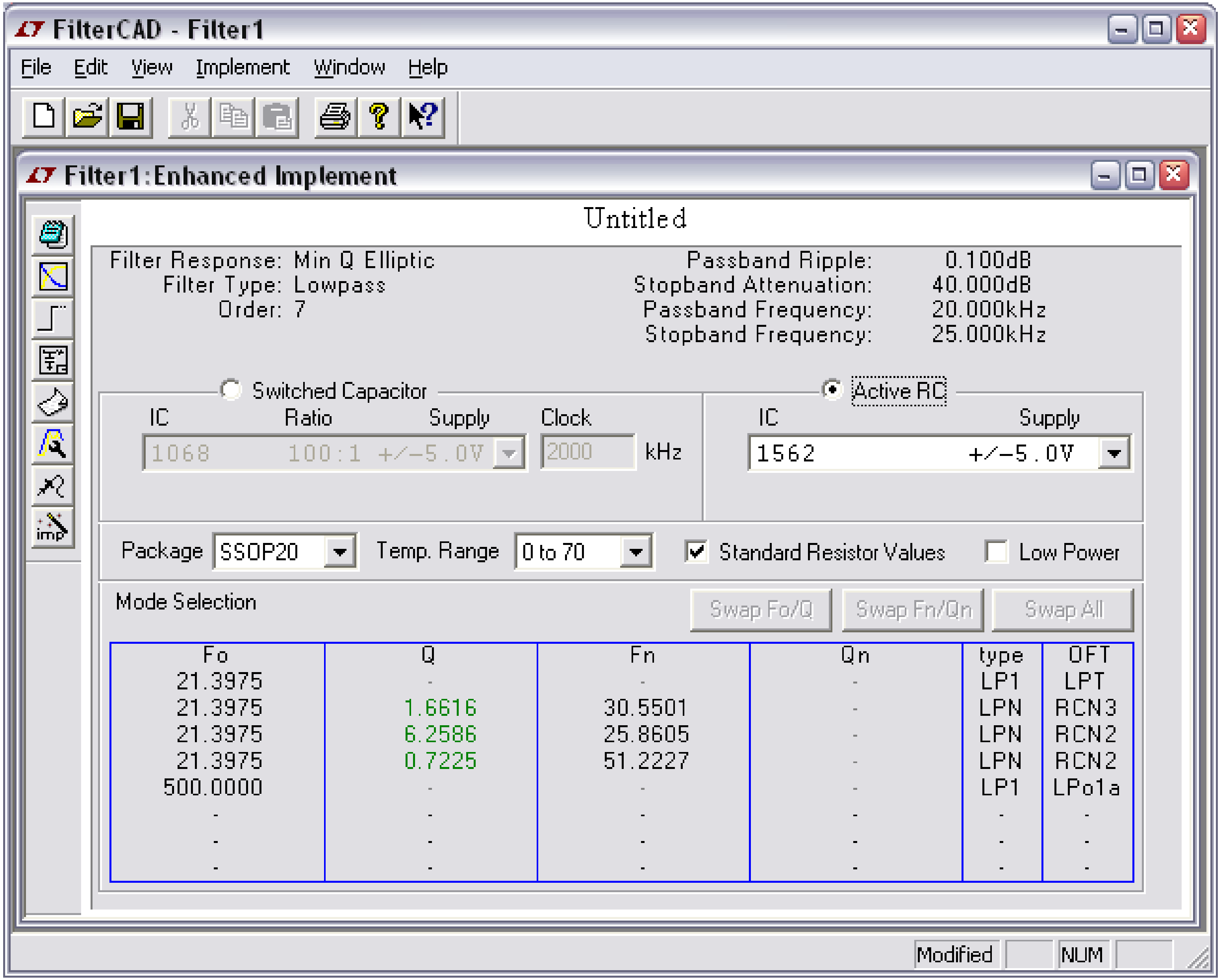
If the quick design procedure does not meet your need, try the Enhanced design procedure.
Enhanced design is a full featured, interactive design and implementation experience. Classical filter approximations and fully custom designs are supported.
Current
NUM

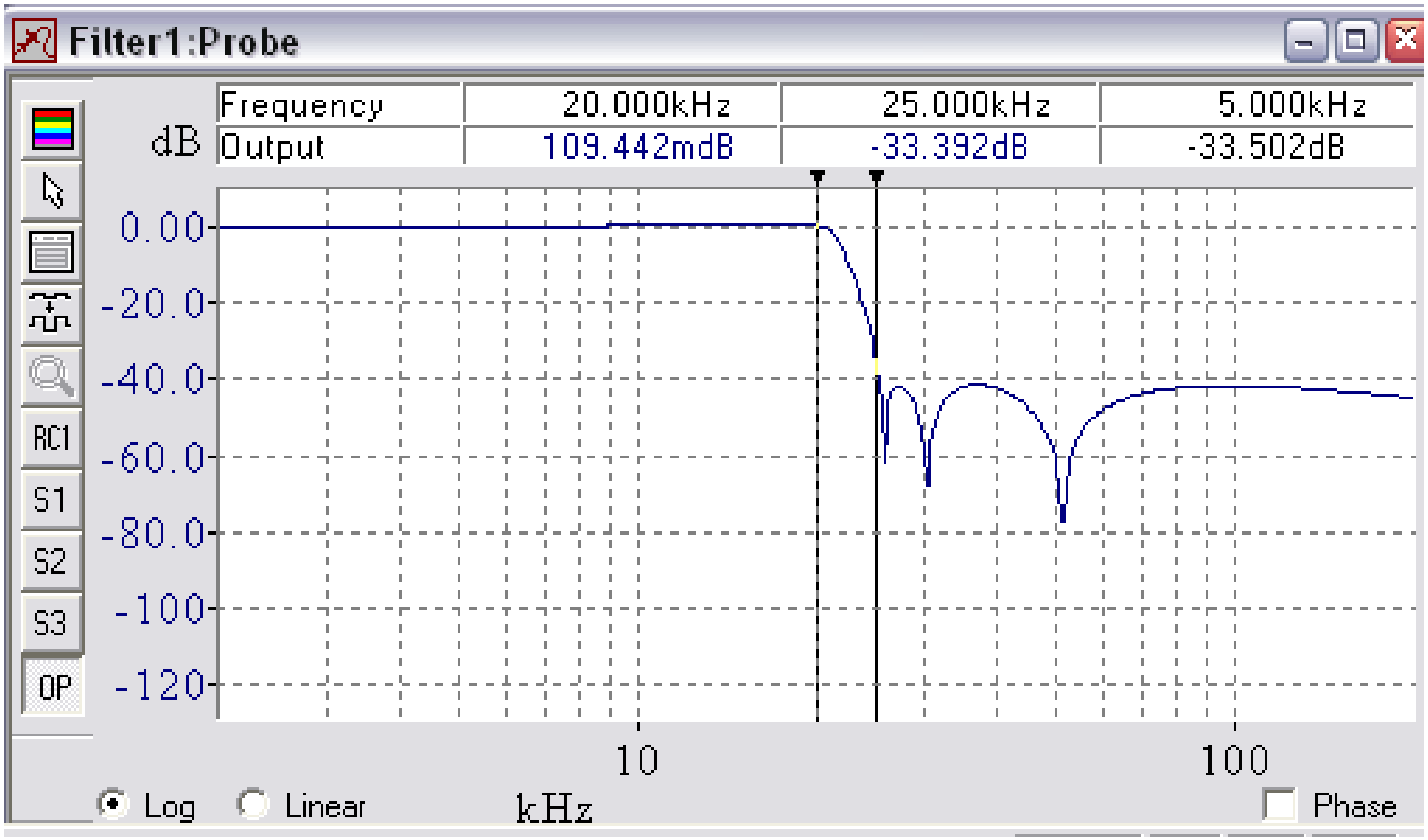

FilterCAD - Filter1
File Edit View Filter Window Help
Filter1:Enhanced Design
Untitled
Filter Type
Lowpass
Highpass
Bandpass
Notch
R
A
Fc
Fs
Amplitudes (dB)
Passband Gain 0
Passband Ripple (R) 0
Stopband Atten. (A) 40
Actual Atten. (at Fs) 42.1
Frequencies
Passband (Fc) 20
Stopband (Fs) 40
Hz
kHz
MHz
Response
Butterworth
Bessel
Chebyshev
Elliptic
Min Q Elliptic
Custom
Order
7
>16
6
4
5
Coefficients
Fo Q Fn
20.0000 - -
20.0000 2.2470 INF
20.0000 0.8019 INF
20.0000 0.5550 INF
Edit window title
Modified
NUM

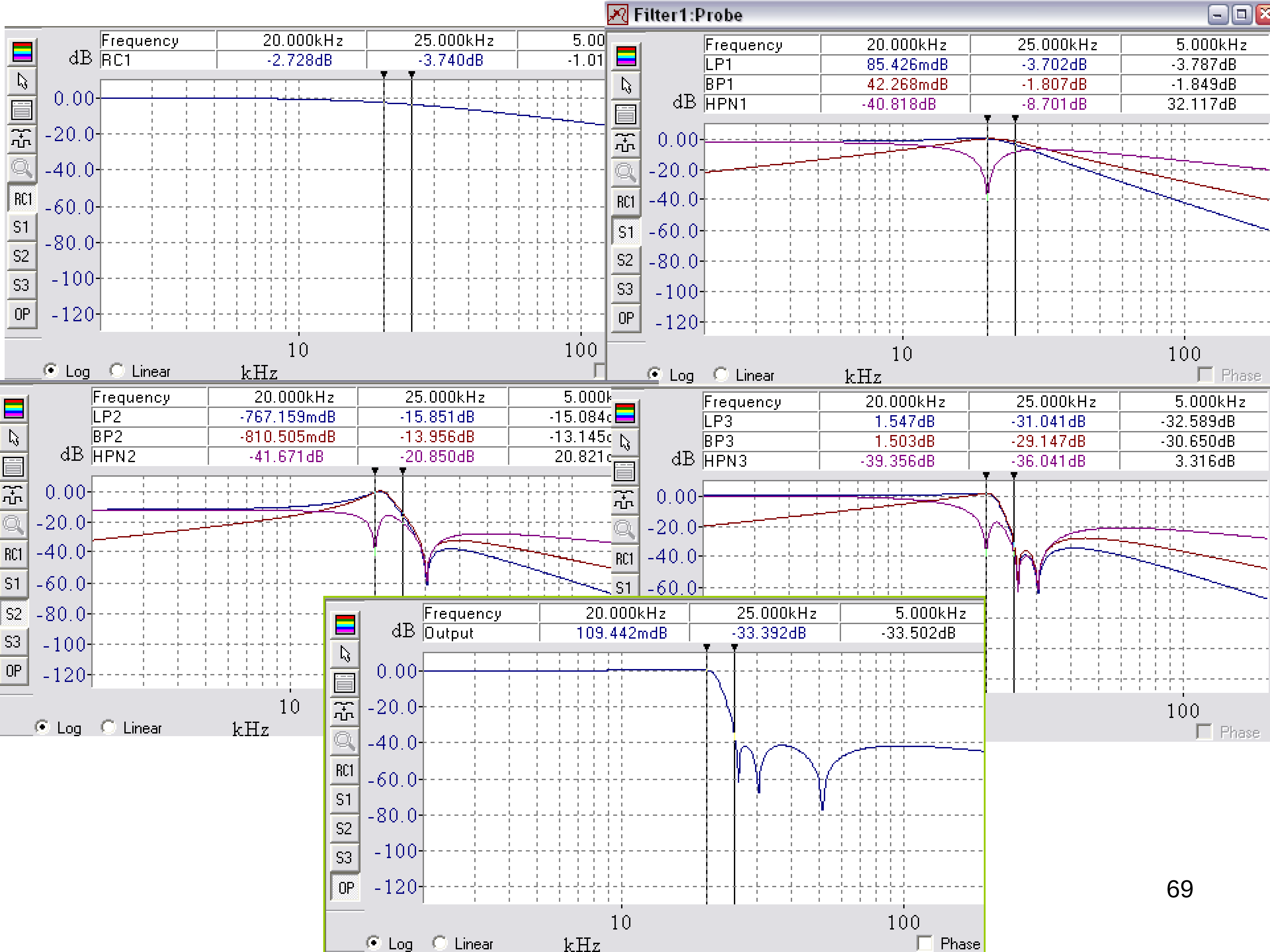

FilterCAD - Filter1
File Edit View Filter Window Help
Filter1:Enhanced Design
Untitled
Filter Type
Lowpass
Highpass
Bandpass
Notch
Amplitudes (dB)
Passband Gain 0
Passband Ripple (R) 0.1
Stopband Atten. (A) 40
Actual Atten. (at Fs) 43.4
Frequencies
Passband (Fc) 20
Stopband (Fs) 25
Hz kHz MHz
Response
Butterworth
Bessel
Chebyshev
Elliptic
Min Q Elliptic
Custom
Order
>16
>16
11
Coefficients
Fo Q Fn
13.3826 0.6294 77.4384
18.5215 1.8728 31.6228
20.7765 8.5342 25.5182
Edit window title
Filter Type
Lowpass
Highpass
Bandpass
Notch
Amplitudes (dB)
Passband Gain 0
Passband Ripple (R) 0.1
Stopband Atten. (A) 40
Actual Atten. (at Fs) 34.0
Frequencies
Passband (Fc) 20
Stopband (Fs) 25
Hz kHz MHz
Response
Butterworth
Bessel
Chebyshev
Elliptic
Min Q Elliptic
Order
>16
>16
11
6
7
Coefficients
Fo Q Fn
21.3975 - -
21.3975 0.7225 51.2227
21.3975 1.6616 30.5501
21.3975 6.2586 25.8605

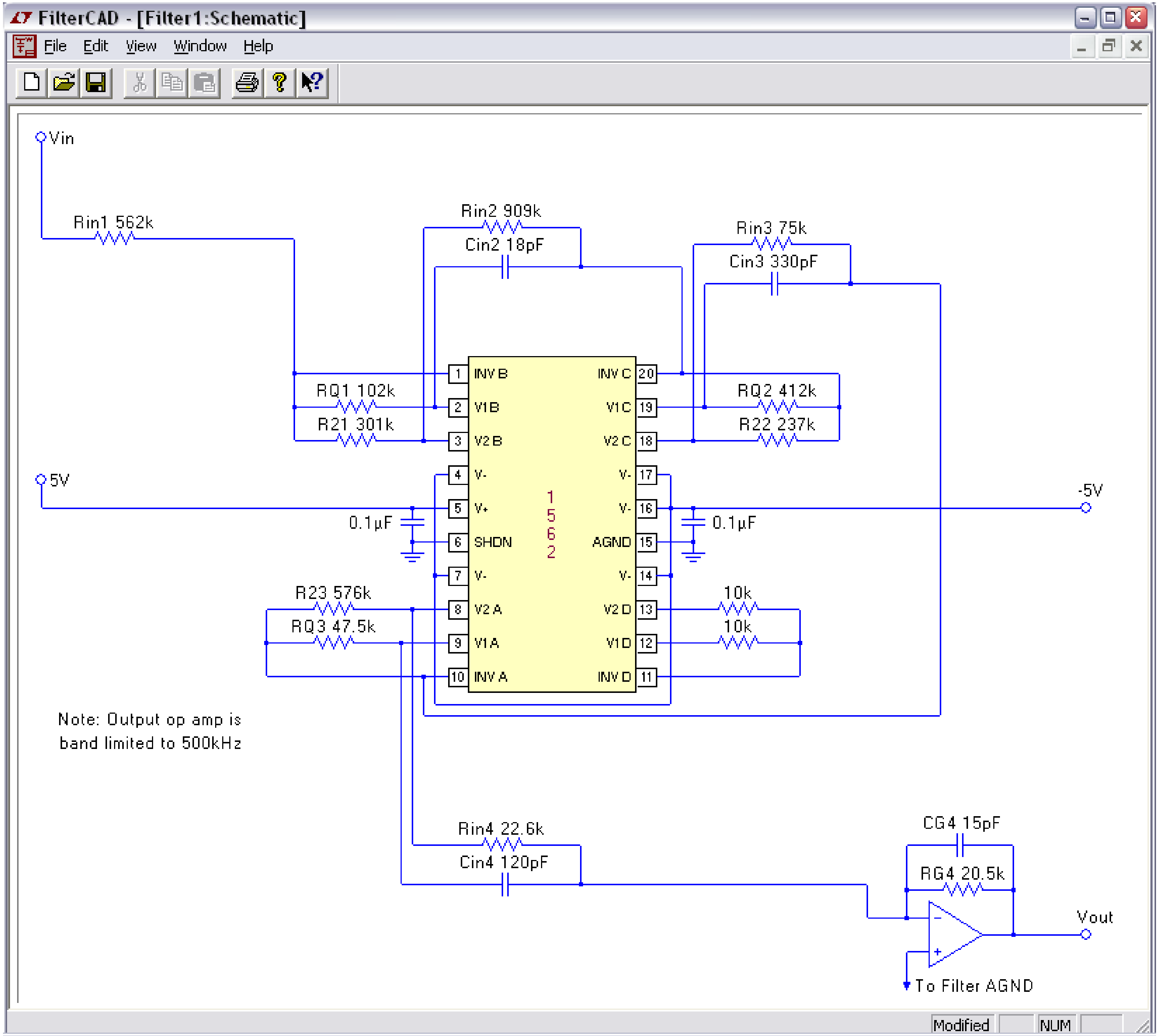

FilterCAD
File Edit Bookmark Options Help
Help Topics Back Print << >>
Minimum Q Elliptic
Minimum Q elliptics have the lowest possible Q while maintaining an elliptic response. They have lower sensitivity and lower attenuation than standard elliptics.
Note: Minimum Q elliptics were first developed by D.M. Rabrenovic and M.D. Lutovac—
see Electronic Letters, Volume 30, Number 3 (February 1994), pp 206–207.


FilterCAD - Filter1
File Edit View Implement Window Help
Filter1:Enhanced Implement
Untitled
Filter Response: Min Q Elliptic
Filter Type: Lowpass
Order: 7
Passband Ripple: 0.100dB
Stopband Attenuation: 40.000dB
Passband Frequency: 20.000kHz
Stopband Frequency: 25.000kHz
Switched Capacitor
IC Ratio Supply Clock
1068 100:1 +/-5.0V 2000 kHz
Active RC
IC Supply
1562 +/-5.0V
Package SSOP28
Temp. Range 0 to 70
Standard Resistor Values
Low Power
Mode Selection
Swap Fo/Q
Swap Fn/Qn
Swap All
Fo Q Fn Qn type mode Rnrm
21.3975 - - - LP1 LPi1 -
21.3975 1.6616 30.5501 - LPN 2n 10
21.3975 6.2586 25.8605 - LPN 2n 10
21.3975 0.7225 51.2227 - LPN 2n 10
Edit window title
Modified
NUM

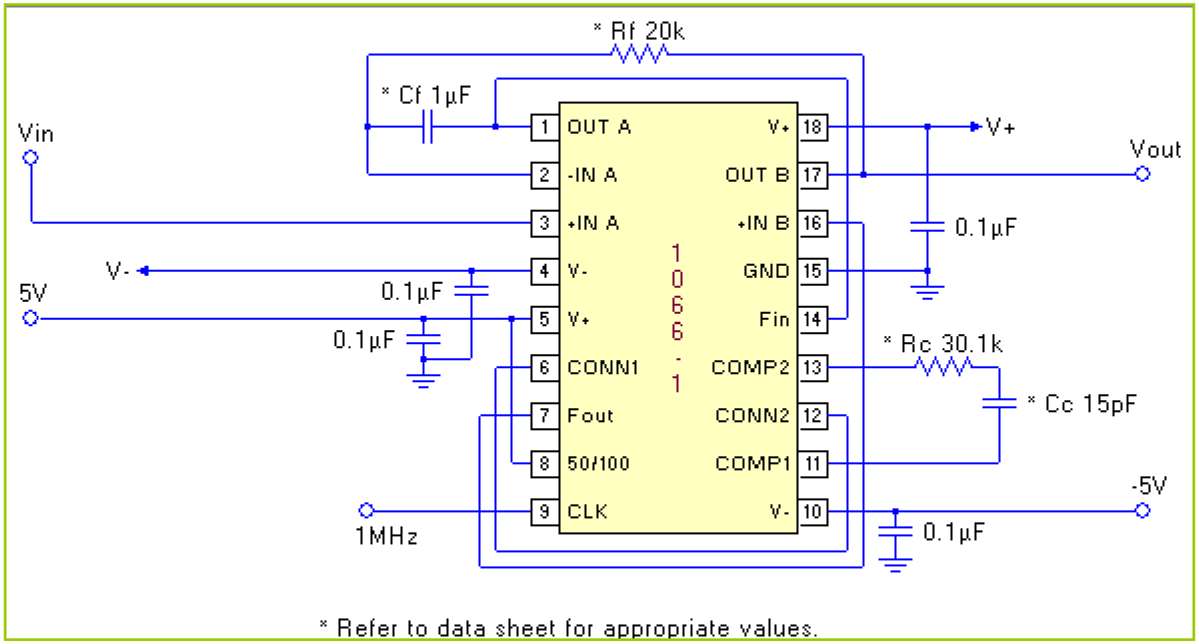

FilterCAD - Filter1
File Edit View Implement Window Help
Filter1:Enhanced Implement
Untitled
Filter Response: Min Q Elliptic
Filter Type: Lowpass
Order: 7
Passband Ripple: 0.100dB
Stopband Attenuation: 40.000dB
Passband Frequency: 20.000kHz
Stopband Frequency: 25.000kHz
Switched Capacitor
IC Ratio Supply Clock
1068 100:1 +/-5.0V 2000 kHz
Active RC
IC Supply
1562 +/-5.0V
Package SSOP20
Temp. Range 0 to 70
Standard Resistor Values
Low Power
Mode Selection
Swap Fo/Q
Swap Fn/Qn
Swap All
Fo Q Fn Qn type OFT
21.3975 - - - LP1 LPT
21.3975 1.6616 30.5501 - LPN RCN3
21.3975 6.2586 25.8605 - LPN RCN2
21.3975 0.7225 51.2227 - LPN RCN2
500.0000 - - - LP1 LPo1a
Modified
NUM

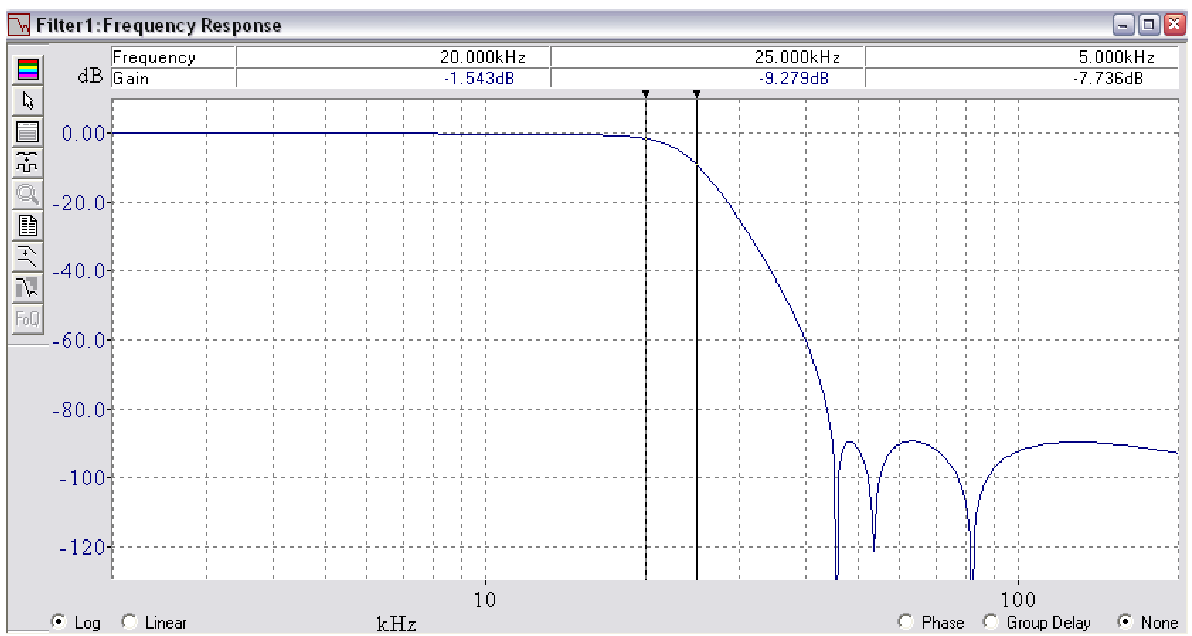

Filter1:Probe
Frequency
20.000kHz
25.000kHz
5.000kHz
dB
Output
109.442mdB
-33.392dB
-33.502dB
0.00
-20.0
-40.0
-60.0
-80.0
-100
-120
RC1
S1
S2
S3
OP
10
100
Log
Linear
kHz
Phase


Filter1:Probe
Frequency 20.000kHz 25.000kHz 5.00
dB RC1 -2.728dB -3.740dB -1.01
0.00 -20.0 -40.0 -60.0 -80.0 -100 -120
10 100
Log Linear kHz
RC1 S1 S2 S3 OP
Frequency 20.000kHz 25.000kHz 5.000kHz
LP1 85.426mdB -3.702dB -3.787dB
BP1 42.268mdB -1.807dB -1.849dB
dB HPN1 -40.818dB -8.701dB 32.117dB
Phase
Frequency 20.000kHz 25.000kHz 5.000k
LP2 -767.159mdB -15.851dB -15.084c
BP2 -810.505mdB -13.956dB -13.145c
dB HPN2 -41.671dB -20.850dB 20.821c
Frequency 20.000kHz 25.000kHz 5.000kHz
LP3 1.547dB -31.041dB -32.589dB
BP3 1.503dB -29.147dB -30.650dB
dB HPN3 -39.356dB -36.041dB 3.316dB
Frequency 20.000kHz 25.000kHz 5.000kHz
dB Output 109.442mdB -33.392dB -33.502dB



FilterCAD - [Filter1:Schematic]
File Edit View Window Help
Vin
Rin1 562k
Rin2 909k
Cin2 18pF
Rin3 75k
Cin3 330pF
RQ1 102k
R21 301k
RQ2 412k
R22 237k
5V
-5V
0.1µF
0.1µF
1562
INV B
V1 B
V2 B
V-
V+
SHDN
V-
V2 A
V1 A
INV A
INV C
V1 C
V2 C
V-
V-
AGND
V-
V2 D
V1 D
INV D
R23 576k
RQ3 47.5k
10k
10k
Note: Output op amp is
band limited to 500kHz
Rin4 22.6k
Cin4 120pF
CG4 15pF
RG4 20.5k
Vout
To Filter AGND
Modified
NUM


* Rf 20k
* Cf 1μF
Vin
OUT A
-IN A
+IN A
V-
V+
CONN1
Fout
50/100
CLK
V+
OUT B
+IN B
GND
Fin
COMP2
CONN2
COMP1
V-
1066-1
V+
Vout
0.1μF
V-
5V
0.1μF
0.1μF
* Rc 30.1k
* Cc 15pF
-5V
1MHz
0.1μF
* Refer to data sheet for appropriate values.


Filter1:Frequency Response
Frequency 20.000kHz 25.000kHz 5.000kHz
dB Gain -1.543dB -9.279dB -7.736dB
0.00
-20.0
-40.0
-60.0
-80.0
-100
-120
10
100
kHz
Log
Linear
Phase
Group Delay
None