```
> restart;
```
This is the basic code to compute transfer functions and possible filters

```
> with(LinearAlgebra):
> Zzs:=<Rs,(1/s/Cs),s*Ls>:m:=Dimension(Zzs);
  Zz1:=<R1,(1/s/C1),R1/(1+R1*C1*s),R1+1/C1/s,s*
  L1+1/s/C1>:n:=Dimension(Zz1);
  Zz2:=<R2,(1/s/C2),R2/(1+R2*C2*s),R2+1/C2/s,s*
  L2+1/C2/s>:o:=Dimension(Zz2);
  Zz3:=<R3,(1/s/C3),s*L3,R3/(1+R3*C3*s),(s*L3+1/s/C3),(L3*s)
  /(1+L3*C3*s^2)>:p:=Dimension(Zz3);
  Zz4:=<R4,(1/s/C4),s*L4,R4/(1+R4*C4*s),(s*L4+1/s/C4),(L4*s)
  /(1+L4*C4*s^2)>:q:=Dimension(Zz4);
  Zz5:=<R5,(1/s/C5),s*L5,R5/(1+R5*C5*s),(s*L5+1/s/C5),(L5*s)
  /(1+L5*C5*s^2)>:r:=Dimension(Zz5);
  ZzL:=<RL,(1/s/CL),s*LL,RL/(1+RL*CL*s),(LL*s)/(1+LL*CL*s^2)
  >:st:=Dimension(ZzL);
```

$$m := 3$$
$$n := 5$$
$$o := 5$$
$$p := 6$$
$$q := 6$$
$$r := 6$$
$$st := 5 \quad \textbf{(1)}$$

```
> with(LinearAlgebra):
```
Variables to be switched in and out

```
  K := Matrix([

  [Zs,Z1,infinity,infinity,infinity,infinity,ZL]

  ]);
```

$$K := \begin{bmatrix} Zs & Z1 & \infty & \infty & \infty & \infty & ZL \end{bmatrix} \quad \textbf{(2)}$$

```
> # c1:=1:c2:=1:c3:=1:c4:=1:c5:=1:c6:=1:c7:=1:
> # Here I define my final K matrix

  if K[1,1]=infinity then c1:=infinity:m:=1 else c1:=1 end
  if:
  if K[1,2]=infinity then c2:=infinity:n:=1 else c2:=1 end
  if:
  if K[1,3]=infinity then c3:=infinity:o:=1 else c3:=1 end
  if:
  if K[1,4]=infinity then c4:=infinity:p:=1 else c4:=1 end
  if:
```

```
  if K[1,5]=infinity then c5:=infinity:q:=1 else c5:=1 end
  if:
  if K[1,6]=infinity then c6:=infinity:r:=1 else c6:=1 end
  if:
  if K[1,7]=infinity then c7:=infinity:st:=1 else c7:=1 end
  if:
> Bb := Matrix(st*r*q*p*o*m*n,7):S:=0:
  for i from 1 to m do
  for j from 1 to n do
  for k from 1 to o do
  for l from 1 to p do
  for ki from 1 to q do #
  for k2i from 1 to r do #
  for k3i from 1 to st do # Use the index in the Bb matrix
  Bb[k3i+S,1] := c1*Zzs(i);
  Bb[k3i+S,2] := c2*Zz1(j);
  Bb[k3i+S,3] := c3*Zz2(k);
  Bb[k3i+S,4] := c4*Zz3(l);
  Bb[k3i+S,5] := c5*Zz4(ki);
  Bb[k3i+S,6] := c6*Zz5(k2i);
  Bb[k3i+S,7] := c7*ZzL(k3i);
  end do;
  S:=S+st: # Use the end of the index here.
  end do;
  end do;
  end do;
  end do;
  end do;
  end do;
> Bb;Z:=Bb:
```

$$\begin{bmatrix} Rs & R1 & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & RL \\ Rs & R1 & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{1}{s\ CL} \\ Rs & R1 & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & s\ LL \\ Rs & R1 & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{RL}{RL\ CL\ s+1} \\ Rs & R1 & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{LL\ s}{LL\ CL\ s^2+1} \\ Rs & \frac{1}{s\ C1} & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & RL \\ Rs & \frac{1}{s\ C1} & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{1}{s\ CL} \\ Rs & \frac{1}{s\ C1} & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & s\ LL \\ Rs & \frac{1}{s\ C1} & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{RL}{RL\ CL\ s+1} \\ Rs & \frac{1}{s\ C1} & \infty\ R2 & \infty\ R3 & \infty\ R4 & \infty\ R5 & \frac{LL\ s}{LL\ CL\ s^2+1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \quad \textbf{(3)}$$

75 × 7 Matrix

```
> count:=0:

> # The main code sits below here. Expand Execution code
  here....

> for i from 1 by 1 to RowDimension(K) do
  unassign('Zs','Z1','Z2','Z3','Z4','Z5','ZL'):
  unassign('Vop','Von','I1a','I2a','v2a','v1a','v1b','v2b',
  'I1b','I2b','Vin','Vip','vx','soln','va','vb','Hs'):

  Zs:= K[i,1];
  Z1:= K[i,2];
  Z2:= K[i,3];
  Z3:= K[i,4];
  Z4:= K[i,5];
  Z5:= K[i,6];
  ZL:= K[i,7];
```

```
a11:=0:
a12:=-1/gm:
a21:=0:
a22:=0:
b11:=a11:
b12:=a12:
b21:=a21:
b22:=a22:
soln:=solve({
(Vip-va)/Zs + (Von-va)/Z3 - I1a + (vx-va)/Z1 + (Vop-va)/Z5
= 0,
(Vin-vb)/Zs + (Vop-vb)/Z3 - I1b + (vx-vb)/Z1 + (Von-vb)/Z5
= 0,
(va-Von)/Z3 + (vx-Von)/Z2 - I2a + (0-Von)/ZL + (Vop-Von)
/Z4 + (vb-Von)/Z5 = 0,
(vb-Vop)/Z3 + (vx-Vop)/Z2 - I2b + (0-Vop)/ZL + (Von-Vop)
/Z4 + (va-Vop)/Z5 = 0,
(Von-vx)/Z2 + (Vop-vx)/Z2 + (va-vx)/Z1 + (vb-vx)/Z1 + I1a
+ I1b + I2a + I2b = 0,
vx+v2a=Von,
vx+v2b=Vop,
vx+v1a=va,
vx+v1b=vb,
v1a = a11*v2a - a12*I2a,
I1a = a21*v2a - a22*I2a,
v1b = b11*v2b - b12*I2b,
I1b = b21*v2b - b22*I2b
},{Vop,Von,I1a,I2a,v2a,v1a,v1b,v2b,I1b,I2b,Vin,Vip,vx})
:assign(soln):
Hs:=(Vop-Von)/(Vip-Vin):count:=count+1:Hs:=simplify(Hs):
H[count]:=simplify(Hs);K_select[count]:=[Zs,Z1,Z2,Z3,Z4,
Z5,ZL];
Z_select:=K_select[count]:
Ts:=Hs:
countn:=0:

LPresult:=Matrix():CountLP:=0:
HPresult:=Matrix():CountHP:=0:
BPresult:=Matrix():CountBP:=0:
BSresult:=Matrix():CountBS:=0:
GE_APresult:=Matrix():CountGE_AP:=0:
HPN_LPNresult:=Matrix():CountHPN_LPN:=0:
```

```
>
  for kk from 1 by 1 to RowDimension(Z) do

  Zs:= K[i,1];Z1:= K[i,2];Z2:= K[i,3];Z3:= K[i,4];Z4:= K[i,
  5];Z5:= K[i,6];ZL:= K[i,7];
  Hs:=simplify(Ts);
  Zs:= Z[kk,1];
  Z1:= Z[kk,2];
  Z2:= Z[kk,3];
  Z3:= Z[kk,4];
  Z4:= Z[kk,5];
  Z5:= Z[kk,6];
  ZL:= Z[kk,7];
  Hs:=simplify(Ts);
  temp:=0:
  dn:=denom(Hs):nm:=numer(Hs):Order:=degree(dn,s);NumOrder:=
  degree(nm,s):TOrder:=Order+NumOrder:
  a:=coeff(dn,s,2):
  b:=coeff(dn,s,1):
  c:=coeff(dn,s,0):
  if a=0 or b=0 or c=0 or TOrder>=5 then temp:=1 end if;
  if temp=1 then a:=1:b:=1:c:=1 end if;
  # if temp=1 then b:=1 end if;
  # if temp=1 then c:=1 end if;
  Q :=(a/b)*sqrt(c/a,symbolic):Q:=simplify(Q,sqrt):
  wo_sqr :=simplify(c/a):
  wo:=sqrt(wo_sqr);
  Bandwidth:=(wo/Q):
  Bandwidth:=collect(Bandwidth,[gm]);
  bhp:=coeff(nm,s,2):
  K_HP:=bhp/a:
  K_HP:=simplify(K_HP);
  bbp:=coeff(nm,s,1):
  K_BP:=bbp/a/Bandwidth:
  K_BP:=simplify(K_BP);
  blp:=coeff(nm,s,0):
  K_LP:=blp/a/wo^2:
  K_LP:=simplify(K_LP);

  if temp=0 and K_BP=0 and K_LP=0 then
  HPresult:=<HPresult,<Z_select|wo|Q|K_HP>>:
  CountHP:=CountHP+1:
```

```
  end if;

  if temp=0 and K_HP=0 and K_LP=0 then
  BPresult:=<BPresult,<Z_select|wo|Q|K_BP>>:
  CountBP:=CountBP+1:
  end if;

  if temp=0 and K_HP=0 and K_BP=0 then
  LPresult:=<LPresult,<Z_select|wo|Q|K_LP>>:
  CountLP:=CountLP+1:
  end if;

  if temp=0 and K_BP=0 and K_HP<>0 and K_LP<>0 then
  BSresult:=<BSresult,<Z_select|wo|Q|K_HP|K_LP>>:
  CountBS:=CountBS+1:
  end if;

  if temp=0 and K_LP=K_HP and K_BP<>0 and K_LP<>0 then

  # print("GE/AP|----Z's--------|----w_o------|------Q------
  |------Qz-----|------K-----|");
  Qz:=K_LP*Q/K_BP:Qz:=simplify(Qz):
  GE_APresult:=<GE_APresult,<Z_select|wo|Q|Qz|K_LP>>:
  CountGE_AP:=CountGE_AP+1:
  end if;

  if temp=0 and K_LP<>0 and K_HP<>0 and K_BP=0 and
  K_LP<>K_HP then

  HPN_LPNresult:=<HPN_LPNresult,<Z_select|wo|Q|K_HP|K_LP>>:
  CountHPN_LPN:=CountHPN_LPN+1:
  end if;

  temp:=0:

  end do: countn;

> unassign('Zs','Z1','Z2','Z3','Z4','Z5','ZL'):
```
Unassign your other variables from your solution

```
  end do:
```

```
> count; # This number represents the number of possible
  impedance combinations
```

$$1 \tag{4}$$

List of all possible transfer functions using between 3 and 4 elements

```
> for fg from 1 by 1 to count do
  print(K_select[fg],TF(fg)=H[fg]);
  print();
  print();
  end do;
```

$$[Zs, Z1, \infty, \infty, \infty, \infty, ZL], TF(1) = \frac{Z1\ ZL\ gm}{Z1 + Zs} \tag{5}$$

```
> sizet:=igcd(CountLP,CountHP,CountBP,CountBS,CountGE_AP,
  CountHPN_LPN):
  print("Summary of all the results");
  print();
  print(K_select[1]);
  print();
  print("There are",CountLP," Lowpass Filters");
  print("There are",CountHP," Highpass Filters");
  print("There are",CountBP," Bandpass Filters");
  print("There are",CountBS," Bandstop Filters");
  print("There are",CountGE_AP," Gain Equalizer/Allpass Filters");
  print("There are",CountHPN_LPN," Highpass or Lowpass Notch
  Filters");
  print();print();

  if sizet<>0 then

  if CountLP<>0 then
  print("LOWPASS|Zs, Z1, Z2, Z3, Z4, Z5, ZL ---|----w_o------|------
  Q------|------KLP-----|");

   for x from 1 by 1 to (CountLP) do
    LP(x):=LPresult[x];print();print(LP_(x),LP(x));
    end do;
  print();
  end if;
  print("-----------------------------------------------");
  print();
  if CountHP<>0 then
  print("HIGHPASS|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q-
  -----|------KHP-----|");
```

```
  for x from 1 by 1 to (CountHP) do
  HP(x):=HPresult[x];print();print(HP_(x),HP(x));
  end do;
end if;print();

print("-------------------------------------------------");
if CountBP<>0 then
print("BANDPASS|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q-
-----|------KBP-----|");

  for x from 1 by 1 to (CountBP) do
  BP(x):=BPresult[x]:print();print(BP_(x),BP(x));
  end do;
end if;print();

print("-------------------------------------------------");
if CountBS<>0 then
print("NOTCH|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q----
--|------KHP-----|------KLP----|");

  for x from 1 by 1 to (CountBS) do
  BS(x):=BSresult[x];print();print(BS_(x),BS(x));
  end do;
end if;print();


print("-------------------------------------------------");
if CountGE_AP<>0 then
  print("GE/AP|Zs, Z1, Z2, Z3, Z4, Z4, Z5, ZL |----w_o------|-----
-Q------|------Qz-----|------K-----|");

  for x from 1 by 1 to (CountGE_AP) do
  GE_AP(x):=GE_APresult[x];print();print(GE_AP_(x),GE_AP(x));
  end do;
end if;print();


print("-------------------------------------------------");
if CountHPN_LPN<>0 then
print("HPN/LPN|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q--
----|------K_HP-----|------K_LP-----|");

 for x from 1 by 1 to (CountHPN_LPN) do
 HPN_LPN(x):=HPN_LPNresult[x];print();print(HPN_LPN_(x),HPN_LPN(x)
);
 end do;
end if;
```

```
end if; # This is the end of the main loop responsible for
printing.
```

"Summary of all the results"

$$[Zs, Z1, \infty, \infty, \infty, \infty, ZL]$$

"There are", 6, " Lowpass Filters"
"There are", 0, " Highpass Filters"
"There are", 6, " Bandpass Filters"
"There are", 1, " Bandstop Filters"
"There are", 0, " Gain Equalizer/Allpass Filters"
"There are", 0, " Highpass or Lowpass Notch Filters"

"LOWPASS|Zs, Z1, Z2, Z3, Z4, Z5, ZL ---|----w_o------|------Q------|------KLP-----|"

$$LP\_(1), \left[\left[Rs, \frac{1}{s\ C1}, \infty, \infty, \infty, \infty, \frac{RL}{CL\ RL\ s + 1}\right], \sqrt{\frac{1}{CL\ RL\ C1\ Rs}}, \frac{CL\ RL\ C1\ Rs\ \sqrt{\frac{1}{CL\ RL\ C1\ Rs}}}{C1\ Rs + CL\ RL}, RL\ gm\right]$$

$$LP\_(2), \left[\left[Rs, \frac{R1}{R1\ s\ C1 + 1}, \infty, \infty, \infty, \infty, \frac{RL}{CL\ RL\ s + 1}\right], \sqrt{\frac{R1 + Rs}{C1\ R1\ Rs\ CL\ RL}}, \frac{C1\ R1\ Rs\ CL\ RL\ \sqrt{\frac{R1 + Rs}{C1\ R1\ Rs\ CL\ RL}}}{CL\ RL\ (R1 + Rs) + C1\ R1\ Rs}, \frac{R1\ RL\ gm}{R1 + Rs}\right]$$

$$LP\_(3), \left[\left[s\ Ls, R1, \infty, \infty, \infty, \infty, \frac{RL}{CL\ RL\ s + 1}\right], \sqrt{\frac{R1}{CL\ RL\ Ls}}, \frac{CL\ RL\ Ls\ \sqrt{\frac{R1}{CL\ RL\ Ls}}}{CL\ RL\ R1 + Ls}, RL\ gm\right]$$

$$LP\_(4),$$

$$\left[\left[s\,Ls,\ \frac{1}{s\,C1},\ \infty,\ \infty,\ \infty,\ \infty,\ \frac{RL}{CL\,RL\,s+1}\right]\ \sqrt{\frac{1}{C1\,Ls}}\ \ \frac{C1\,Ls\sqrt{\frac{1}{C1\,Ls}}}{CL\,RL}\ \ RL\,gm\right]$$

$$LP\_(5),\left[\left[s\,Ls,\ \frac{R1}{R1\,s\,C1+1},\ \infty,\ \infty,\ \infty,\ \infty,\ RL\right]\ \sqrt{\frac{1}{C1\,Ls}}\ \ C1\,R1\sqrt{\frac{1}{C1\,Ls}}\ \ RL\,gm\right]$$

$$LP\_(6),\left[\left[s\,Ls,\ \frac{R1}{R1\,s\,C1+1},\ \infty,\ \infty,\ \infty,\ \infty,\ \frac{RL}{CL\,RL\,s+1}\right],\sqrt{\frac{R1}{Ls\ (C1\,R1+CL\,RL)}},\ \frac{Ls\ (C1\,R1+CL\,RL)\sqrt{\frac{R1}{Ls\ (C1\,R1+CL\,RL)}}}{CL\,RL\,R1+Ls},\ RL\,gm\right]$$

"----------"

"----------"

"BANDPASS|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q------|------KBP-----|"

$$BP\_(1),\left[\left[Rs,\ \frac{1}{s\,C1},\ \infty,\ \infty,\ \infty,\ \infty,\ \frac{LL\,s}{CL\,LL\,s^2+1}\right],\sqrt{\frac{1}{CL\,LL}},\ \frac{CL\,LL\sqrt{\frac{1}{CL\,LL}}}{C1\,Rs},\ \frac{LL\,gm}{C1\,Rs}\right]$$

$$BP\_(2),\left[\left[Rs,\ \frac{R1}{R1\,s\,C1+1},\ \infty,\ \infty,\ \infty,\ \infty,\ \frac{LL\,s}{CL\,LL\,s^2+1}\right],\sqrt{\frac{1}{CL\,LL}},\ \frac{CL\,LL\ (R1+Rs)\sqrt{\frac{1}{CL\,LL}}}{C1\,R1\,Rs},\ \frac{LL\,gm}{C1\,Rs}\right]$$

$$BP\_(3),\left[\left[\frac{1}{s\,Cs},\,R1,\,\infty,\,\infty,\,\infty,\,\infty,\,\frac{RL}{CL\,RL\,s+1}\right],\sqrt{\frac{1}{CL\,RL\,Cs\,R1}},\right.$$
$$\left.\frac{CL\,RL\,Cs\,R1\sqrt{\frac{1}{CL\,RL\,Cs\,R1}}}{CL\,RL+Cs\,R1},\,\frac{R1\,RL\,gm\,Cs}{CL\,RL+Cs\,R1}\right]$$

$$BP\_(4),\left[\left[\frac{1}{s\,Cs},\,\frac{R1}{R1\,s\,C1+1},\,\infty,\,\infty,\,\infty,\,\infty,\,\frac{RL}{CL\,RL\,s+1}\right],\sqrt{\frac{1}{R1\,(Cs+C1)\,CL\,RL}},\right.$$
$$\left.\frac{R1\,(Cs+C1)\,CL\,RL\sqrt{\frac{1}{R1\,(Cs+C1)\,CL\,RL}}}{R1\,(Cs+C1)+CL\,RL},\,\frac{RL\,R1\,gm\,Cs}{R1\,(Cs+C1)+CL\,RL}\right]$$

$$BP\_(5),$$
$$\left[\left[s\,Ls,\,R1,\,\infty,\,\infty,\,\infty,\,\infty,\,\frac{LL\,s}{CL\,LL\,s^2+1}\right],\sqrt{\frac{1}{CL\,LL}},\,\frac{CL\,LL\,R1\sqrt{\frac{1}{CL\,LL}}}{Ls},\right.$$
$$\left.\frac{R1\,LL\,gm}{Ls}\right]$$

$$BP\_(6),$$
$$\left[\left[s\,Ls,\,\frac{R1}{R1\,s\,C1+1},\,\infty,\,\infty,\,\infty,\,\infty,\,s\,LL\right],\sqrt{\frac{1}{C1\,Ls}},\,C1\,R1\sqrt{\frac{1}{C1\,Ls}},\right.$$
$$\left.\frac{R1\,LL\,gm}{Ls}\right]$$

"----------"

"NOTCH|Zs, Z1, Z2, Z3, Z4, Z5, ZL |----w_o------|------Q------|------KHP-----|------KLP----|"

$$BS\_(1),$$
$$\left[\left[Rs,\,s\,L1+\frac{1}{s\,C1},\,\infty,\,\infty,\,\infty,\,\infty,\,RL\right]\,\sqrt{\frac{1}{C1\,L1}}\quad\frac{L1\sqrt{\frac{1}{C1\,L1}}}{Rs}\quad RL\,gm\quad RL\,gm\right]$$

"----------"

"---" (6)