Bandpass pole-placer example

++++++++++++++++++++++++++++++++++ EXAMPLE 1 ++++++++++++++++++++++++++++++++

Problem: Design a filter having a passband from 70 to 130 Mhz while maintaining at least 45 dB attenuation below 50 MHz, 45 dB between 150 and 200 MHz, and at lease 34.5 dB above 200 MHz.

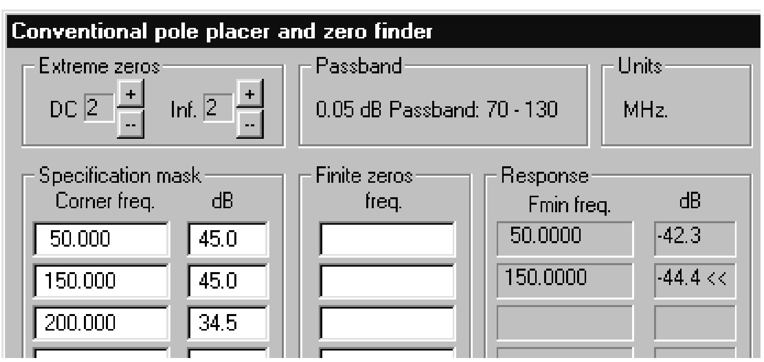
++

Enter the passband specifications on the parameters menu:

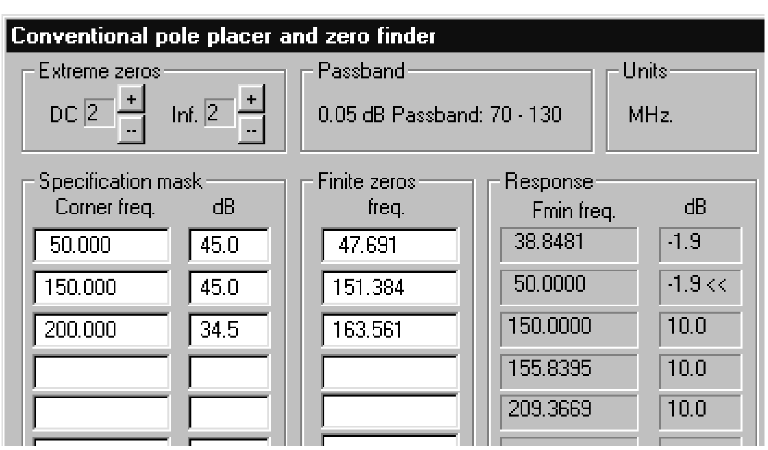
```
passband Ripple (0=Butt. dB) 0.05
arithmetic Fo.          MHz. 100
Bandwidth               MHz. 60
design Zo.                   50
tYpe: 1=sing 2=doub 3=ratio  2
```

Press the [CALCULATE] button and enter the following mask into the pole placer dialog box:

```
Infinite zeros: DC=2    INf=2
50 MHz,  45 dB
150 MHz, 45 dB
200 MHz, 34.5 dB
```

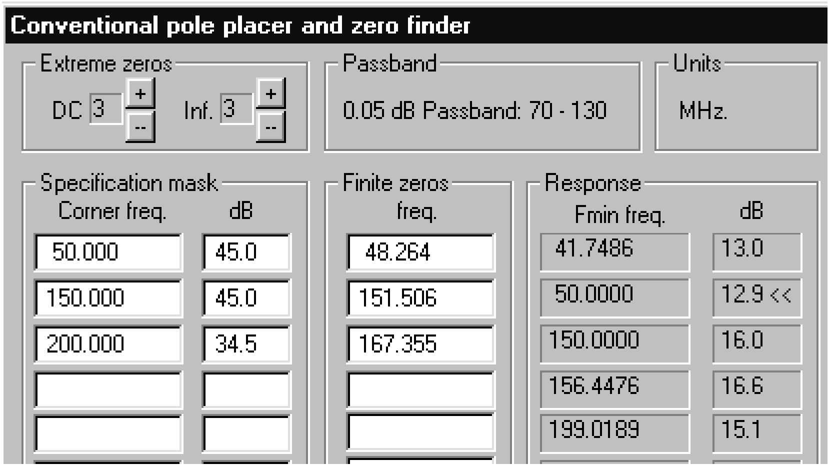


The “Response” area of the dialog box will always display the results of the zeros you have set up if it can. In this case, we have 2 zeros at DC and 2 at infinite frequency. This represents a second order (N=2) all-pole filter. This is equivalent to an N=2. .05 dB ripple direct scaled filter. Needless to say, this will not satisfy the requirement. To begin adding finite zero notch sections to the filter simply press the [Solve] button. The results are shown next

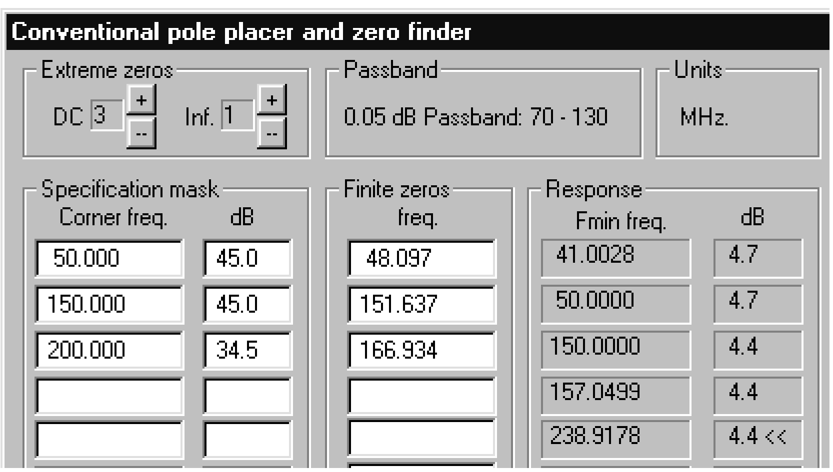


The response is lacking on the low side of the passband. By using the [Solve] button again the extreme zeros will each be incremented by 1. This results in 3 at DC and 3 at infinite frequency. Do this to maintain the same number of finite zeros.

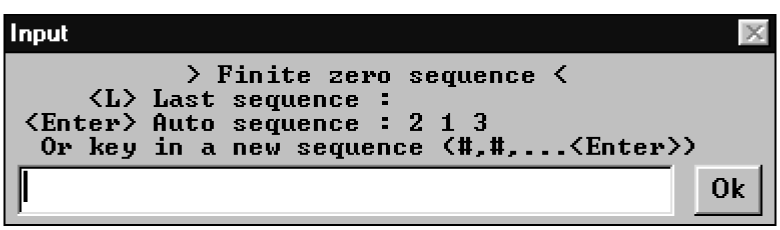
The next figure shows what the response will be with 3 and 3 extreme zeros.



With 3 and 3 extreme zeros the margins are excessive in the upper stopband. By changing the zeros to 3 at DC and 1 at infinity this imbalance can be corrected.



All of the attenuation margins, now being about 4.5 dB, will be considered satisfactory for this example, so we can continue with this design by pressing the [exit and synthesize] button. The next prompt will ask for the order in which the finite zeros are to appear in the final design. The best order is usually that which produces the smallest load/source impedance ratio and lowest parts value spread in the final design. This is usually provided by the Auto sequence option. You may specify the order manually by using the numbers of each notch frequency as they would be if they were listed in ascending order, such as 1,2,3 for ascending order, or 3,2,1 for descending order, etc.



Choose the Auto sequence option by pressing the [Ok] button or the keyboard <Enter> key. The synthesis section will follow.

```
═══════════════════════════> Sub-network codes <═══════════════════════════
 CODE   Schematic     CODE   Schematic    CODE   Schematic     CODE   Schematic

   1   ─── C ───        2    ───┬───        3   ─── L ───        4    ───┬───
                                L                                        C
                             ───┴───                                  ───┴───
 ─── C ───┬───────             ─── L ───┬───────
   5      L             6   ┌─ L ─┐       7      L              8   ┌─ L ─┐
          │             ────┬───┤     ├───       │              ────┬───┤     ├───
          C f-              L   └─ C ─┘ f-       C f+               C   └─ C ─┘ f+
 ─────────┴───────      ────┴────────────   ─────────┴───────   ────┴────────────

 ENTER THE CODES FOR THE FILTER STRUCTURE     (R)-Recall last manual entry.
   (Start at termination end.)  Zeros: Dc= 3  Inf.= 1  Finite order= +-+
```

`back	Code 1	Code 2	Code 3	Code 4	Recall last
?-help	Code 5	Code 6	Code 7	Code 8	Automatic

by simply pressing the [Automatic] button the pole placer will close and exit back to the main control menu choosing the default topology .

At this point, most designs will require transformation to minimize part value spread and to add capacitors at nodes critical to distributed capacity. To do this we will use the circuit editor.

```
 0  ┌─ Termination ─┐          50 Ohms
 1  ├────── L ──────┤      52.101 nHy.
 2  ├────── C ──────┤      42.146 pFd.
    │             ┌─┴─┐
 3. │             C   L     27.27 pFd.      40.407 nHy.  Fx = 151.62 MHz.
    │             └─┬─┘
    │               │
 5  │               C      29.762 pFd.
    │               │
 6. ├─── C ─── L ───┤       198.3 pFd.      55.218 nHy.  Fx = 48.097 MHz.
 8  ├────── C ──────┤      63.714 pFd.
    │             ┌─┴─┐
 9. │             C   L    15.093 pFd.      60.501 nHy.  Fx = 166.55 MHz.
    │             └─┬─┘
    │               │
11  │               C      26.451 pFd.
    │               │
12  ├────── C ──────┤      47.794 pFd.
13  ├────── L ──────┤      49.988 nHy.
14  └──── Source ───┘       47.97 Ohms
15   Fc = 95.394 MHz.
```

Let's start by scaling the impedance of the entire network to achieve good values at the source end. 80 Ohms should do the job.

>**[SCALE:] Src-Zo**

What new source Zo ? 80

```
  8 ├────── C ──────┤         38.206 pFd.
                    ┌─┴─┐
  9.│              C   L      9.0506 pFd.       100.89 nHy.  Fx = 166.55 MHz.
    │               └─┬─┘
    │                 │
 11 │                 C       15.861 pFd.
    │                 │
 12 ├────── C ──────┤          28.66 pFd.
 13 ├────── L ──────┤         83.361 nHy.
 14 └──── Source ───┘             80 Ohms
 15  Fc = 95.394 MHz.
```

Now, a capacitor should pad the node between the "tank" at branches 9 and 10 and the capacitor at branch 11. A Norton transform with a ratio less than 1.0 will generate this capacitor and improve the L/C ratio of the series "tank" at the same time. Identify the branch to support the transform my highlighting the value of the capacitor value at branch 11. Simply click on the 15.816 pFd. Value with your mouse LEFT button.

> **[NORT:] Xform**
Preset ratio = 1.0000
Impedance ratio ? > .8

```
  8 ├────── C ──────┤         47.757 pFd.
                    ┌─┴─┐
  9.│              C   L      11.313 pFd.       80.715 nHy.  Fx = 166.55 MHz.
    │               └─┬─┘
 11 ├────── C ──────┤         2.0932 pFd.
    │                 │
 12 │                 C       17.734 pFd.
    │                 │
 13 ├────── C ──────┤         26.787 pFd.
 14 ├────── L ──────┤         83.361 nHy.
 15 └──── Source ───┘             80 Ohms
 16  Fc = 95.394 MHz.
```

To do the same operation at the next section requires that the order of the series capacitor and "notch section" between branches 3 and 5 be reversed. This is because a Norton transform with a ratio greater than 1.0 is needed here. This would generate a negative capacitor on the high Zo side where there is nothing to absorb it.

Highlight branch 3 value with your mouse (20.441 pFd.).

```
  0 ┌─ Termination ─┐          66.71 Ohms
  1 ├────── L ──────┤         69.508 nHy.
  2 ├────── C ──────┤         31.591 pFd.
                    ┌─┴─┐
  3.│              C   L      20.441 pFd.       53.908 nHy.  Fx = 151.62 MHz.
    │               └─┬─┘
    │                 │
  5 │                 C       22.309 pFd.
    │                 │
  6.├──── C ── L ───┤         148.64 pFd.       73.667 nHy.  Fx = 48.097 MHz.
  8 ├────── C ──────┤         47.757 pFd.
                    ┌─┴─┐
  9.│              C   L      11.313 pFd.       80.715 nHy.  Fx = 166.55 MHz.
    │               └─┬─┘
 11 ├────── C ──────┤         2.0932 pFd.
    │                 │
```

```
12 │                C       17.734 pFd.
   │                │
13 ├────── C ──────┤       26.787 pFd.
14 ├────── L ──────┤       83.361 nHy.
15 └──── Source ───┘           80 Ohms
16  Fc = 95.394 MHz.
```

> **[NORT:] Move**
Position them After what branch number ? >5

```
 0 ┌─ Termination ─┐        66.71 Ohms
 1 ├────── L ──────┤       69.508 nHy.
 2 ├────── C ──────┤       31.591 pFd.
   │               │
 3 │               C       22.309 pFd.
   │               │
   │             ┌─┴─┐
 4.│             C   L     20.441 pFd.       53.908 nHy.  Fx = 151.62 MHz.
   │             └─┬─┘
 6.├─── C ─── L ───┤       148.64 pFd.       73.667 nHy.  Fx = 48.097 MHz.
 8 ├────── C ──────┤       47.757 pFd.
   │             ┌─┴─┐
 9.│             C   L     11.313 pFd.       80.715 nHy.  Fx = 166.55 MHz.
   │             └─┬─┘
11 ├────── C ──────┤       2.0932 pFd.
   │               │
12 │               C       17.734 pFd.
   │               │
13 ├────── C ──────┤       26.787 pFd.
14 ├────── L ──────┤       83.361 nHy.
15 └──── Source ───┘           80 Ohms
16  Fc = 95.394 MHz.
```

Now the transform can be done because the negative value will be absorbed in the capacitor at branch 2.
Highlight the capacitor value at branch 3 and do the transform.

> **[NORT:] Xform**
Impedance ratio? > 1.25

```
 0 ┌─ Termination ─┐        80.05 Ohms
 1 ├────── L ──────┤        83.41 nHy.
 2 ├────── C ──────┤       24.551 pFd.
   │               │
 3 │               C       20.365 pFd.
   │               │
 4 ├────── C ──────┤       1.9437 pFd.
   │             ┌─┴─┐
 5.│             C   L     20.441 pFd.       53.908 nHy.  Fx = 151.62 MHz.
   │             └─┬─┘
 7.├─── C ─── L ───┤       148.64 pFd.       73.667 nHy.  Fx = 48.097 MHz.
 9 ├────── C ──────┤       47.757 pFd.
   │             ┌─┴─┐
10.│             C   L     11.313 pFd.       80.715 nHy.  Fx = 166.55 MHz.
   │             └─┬─┘
12 ├────── C ──────┤       2.0932 pFd.
```

```
     │                   │
13   │                   C       17.734 pFd.
     │                   │
14   ├─────── C ─────────┤       26.787 pFd.
15   ├─────── L ─────────┤       83.361 nHy.
16   └───── Source ──────┘           80 Ohms
17   Fc = 95.394 MHz.
```

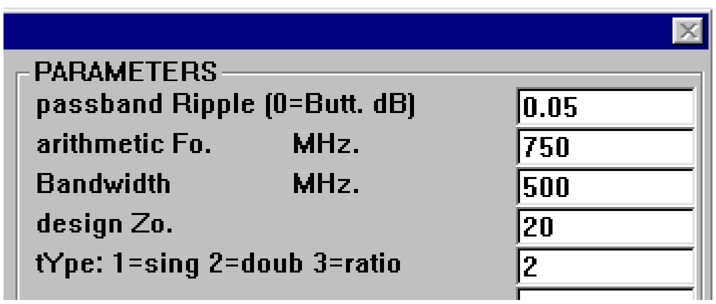
This looks good enough, we can exit from the circuit editor and apply impedance matching using the (S) and (T) matching options of the UTILITIES menu to get to the normally desired 50 Ohm level.

+++++++++++++++++++++++++++++++++ EXAMPLE 2 +++++++++++++++++++++++++++++++

Problem: Design an equal ripple tubular filter with a "ripple" passband from 500 MHz to 1000 MHz. As this represents a 67% bandwidth, design by conventional lowpass scaling procedures would no work, the filter must be directly synthesized.

+++

In this case, we already know that a 5 section filter will meet our requirements. A tubular filter only has 1 zero at Dc, and will have 2N-1 zeros at infinite frequency. The pole placer section is not required and we can key in the requirements directly.



Begin with the parameters menu and key in the passband requirements which are: .05 dB passband ripple, 20 Ohms design Zo, Fo of 750 MHz. and a bandwidth of 500 MHz.

Press the [CALCULATE] button

Set the extreme zeros to 1 at DC and 9 at Infinity.

Press the [eXit and synthesize] button

Upon exit, the synthesis screen will appear:

```
═══════════════════════════════> Sub-network codes <══════════════════════════
 CODE  Schematic    CODE  Schematic   CODE  Schematic    CODE  Schematic

  1  ── C ──         2  ──┬──         3  ── L ──          4  ──┬──
                          L                                    C
                        ──┴──                                ──┴──
 ── C ─┬────                        ── L ─┬────
  5    L             6   ┌─ L ─┐     7    L              8   ┌─ L ─┐
       │            ──┬──┤     ├──        │             ──┬──┤     ├──
       C f-           L  └─ C ─┘ f-       C f+            C  └─ C ─┘ f+
 ──────┴────        ──┴─────────     ─────┴────         ──┴─────────

ENTER THE CODES FOR THE FILTER STRUCTURE     (R)-Recall last manual entry.
  (Start at termination end.)  Zeros: Dc= 1  Inf.= 9  Finite order= None
```

Press the [Automatic] button.

At this point the filter must be transformed using the circuit editor. The circuit editor begins by drawing the schematic:

```
 0  ┌─ Termination ─┐          20 Ohms
 1  │               L      6.3362 nHy.
 2  │               C      8.3424 pFd.
 3  ├────── C ──────┤      21.578 pFd.
 4  │               L      2.0556 nHy.
 5  ├────── C ──────┤      122.54 pFd.
 6  │               L     0.38477 nHy.
 7  ├────── C ──────┤       624.4 pFd.
 8  │               L     0.07917 nHy.
 9  ├────── C ──────┤      2009.4 pFd.
10  │               L    0.018972 nHy.
11  └──── Source ───┘     0.05988 Ohms
12  Fc = 707.11 MHz.
```

The network must first be flipped end for end using the circuit editor to bring the end having the design impedance (20 Ohms) to the source.

>**[MAIN:] Reverse**

```
 0 ┌─ Termination ─┐       0.05988 Ohms
   │               │
 1 │               L      0.018972 nHy.
   │               │
 2 ├────── C ──────┤        2009.4 pFd.
   │               │
 3 │               L       0.07917 nHy.
   │               │
 4 ├────── C ──────┤         624.4 pFd.
   │               │
 5 │               L       0.38477 nHy.
   │               │
 6 ├────── C ──────┤        122.54 pFd.
   │               │
 7 │               L        2.0556 nHy.
   │               │
 8 ├────── C ──────┤        21.578 pFd.
   │               │
 9 │               C        8.3424 pFd.
   │               │
10 │               L        6.3362 nHy.
   │               │
11 └──── Source ───┘            20 Ohms
12  Fc = 707.11 MHz.
```

In order to equalize the terminations and insert the additional capacitors need to form a tubular circuit, we must perform Norton transforms at each shunt coupling, The correct impedance ratio is equal to:

```
ratio = (Rs/Rt)^(1/(n-1)) = (20/.05988)^(1/(5-1)) = 4.28
```

Because an additional editor feature will be used to finalize the impedance ratio, the actual ratio used for each transform need only be approximate. Let's use 4:

>**[NORT:] eXform**
At what branch? 8
Impedance ratio (-1 for preset)? 4

>**[NORT:] eXform**
At what branch? 6
Impedance ratio (-1 for preset)? 4

>**[NORT:] eXform**
At what branch? 4
Impedance ratio (-1 for preset)? 4

>**[NORT:] eXform**
At what branch? 2
Impedance ratio (-1 for preset)? 4

```
 0  ┌─ Termination ─┐          15.33 Ohms
    │               │
 1  │               L        4.8568 nHy.
    │               │
 2  │               C        15.698 pFd.
    │               │
 3  ├──────  C  ────┤        15.698 pFd.
    │               │
 4  │               L        5.0669 nHy.
    │               │
 5  │               C        51.551 pFd.
    │               │
 6  ├──────  C  ────┤        19.513 pFd.
    │               │
 7  │               L        6.1564 nHy.
    │               │
 8  │               C        25.214 pFd.
    │               │
 9  ├──────  C  ────┤        15.317 pFd.
    │               │
10  │               L        8.2224 nHy.
    │               │
11  │               C        16.654 pFd.
    │               │
12  ├──────  C  ────┤        10.789 pFd.
    │               │
13  │               C        13.601 pFd.
    │               │
14  │               L        6.3362 nHy.
    │               │
15  └──── Source ───┘            20 Ohms
16  Fc = 707.11 MHz.
```

The Equal Value feature will now be used to equalize the load and source Zo and make all of the section inductors equal as well. The "equal C" option is also available and could be used here.

>**[MIS2:] Equal value**
Equal L or C ? L
Value desired (nHy.) ? 15

```
 0  ┌─ Termination ─┐          47.35 Ohms
    │               │
 1  │               C        4.9785 pFd.
    │               │
 2  │               L            15 nHy.
    │               │
 3  ├──────  C  ────┤        5.1916 pFd.
    │               │
 4  │               C        14.822 pFd.
    │               │
 5  │               L            15 nHy.
    │               │
 6  ├──────  C  ────┤        7.2653 pFd.
    │               │
 7  │               C        9.4976 pFd.
    │               │
 8  │               L            15 nHy.
    │               │
```

```
  9 ├────── C ──────┤        7.2653 pFd.
                    │
 10 │               C        14.822 pFd.
    │               │
 11 │               L            15 nHy.
    │               │
 12 ├────── C ──────┤        5.1916 pFd.
    │               │
 13 │               C        4.9785 pFd.
    │               │
 14 │               L            15 nHy.
    │               │
 15 └──── Source ───┘         47.35 Ohms
```
16 Fc = 707.11 MHz.

A tubular requires that each shunt coupling be transformed into a "pi" configuration by splitting each of the series section capacitors in two at all but the end sections. Only the source end sections are shown in the example:

>**[NORT:] Split**

At what branch? 10

```
  9 ├────── C ──────┤        7.2653 pFd.
    │               │
 10 │               C        29.644 pFd.
    │               │
 11 │               C        29.644 pFd.
    │               │
 12 │               L            15 nHy.
    │               │
 13 ├────── C ──────┤        5.1916 pFd.
    │               │
 14 │               C        4.9785 pFd.
    │               │
 15 │               L            15 nHy.
    │               │
 16 └──── Source ───┘         47.35 Ohms
 17  Fc = 707.11 MHz.
```

>**[NORT:] Interchange**

What two branches ? 11,12

```
  9 ├────── C ──────┤        7.2653 pFd.
    │               │
 10 │               C        29.644 pFd.
    │               │
 11 │               L            15 nHy.
    │               │
 12 │               C        29.644 pFd.
    │               │
 13 ├────── C ──────┤        5.1916 pFd.
    │               │
 14 │               C        4.9785 pFd.
    │               │
 15 │               L            15 nHy.
    │               │
 16 └──── Source ───┘         47.35 Ohms
 17  Fc = 707.11 MHz.
```

>[NORT:] Pi-T

At what center branch? 13

```
  9 ├────── C ──────┤       7.2653 pFd.
    │               │
 10 │               C       29.644 pFd.
    │               │
 11 │               L           15 nHy.
    │               │
 12 ├────── C ──────┤       3.8654 pFd.
    │               │
 13 │               C       3.7068 pFd.
    │               │
 14 ├────── C ──────┤      0.64918 pFd.
    │               │
 15 │               L           15 nHy.
    │               │
 16 └──── Source ───┘        47.35 Ohms
 17  Fc = 707.11 MHz.
```

It is a good idea to save the final design with the [MIS1:] Save command so that a change in Zo could be made later if necessary. The 47 Ohm level dictated by the 15 nHy inductors requested might be too high. This could be done with the[Scale:] Src-Zo feature. In general, an impedance level as close to the final level desired as possible will minimize distortion caused by the narrow band nature of the shunt capacitor matching scheme used.

This Split - Interchange- Pi-T procedure must be done at all remaining sections. Next we can exit from the circuit editor and use the (S) and (T) impedance matching feature of the UTILITIES menu to finalize the design adding the "end slugs".

The equal value feature of the circuit editor is also capable of making the shunt capacitors around each coupling equal in value AFTER the matcher has been used. This can be done if it is desired to make the second and third shunt capacitor pair equal as well as the other shunt pairs.