Build Filters Without PC Boards

When one or a few units are needed, passive components can be constructed quickly with no need for a printed circuit board

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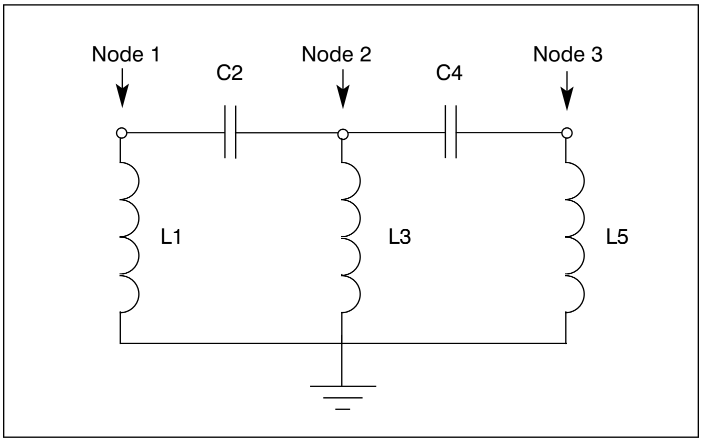
When stand alone passive components are not readily available as standard off the shelf commercial units, lab-built engineering models are often the best solution. At other times, passive circuits may be critically needed as test accessories when unanticipated problems arise during final subsystem and system testing. In these situations, time constraints can be met with prototype units that can be designed, assembled, and tested in only a few hours, as long as printed circuit boards (PC boards) are not used.

This types of component construction is readily accomplished at low power levels with frequencies below 100 MHz. At VHF, passive circuits such as bandpass filters can be readily implemented using standard die cast aluminum boxes as housings. Coaxial connectors and some of the circuit elements are screw assembled to the housing. Other circuit elements are assembled using soldered connections inside the housing.

Many standard commercial components are regularly manufactured without PC boards, but are available for surface mounting to higher level PC boards. They include passive units such as low pass and high pass filters, equalizers, attenuators, terminations, RF transformers, DC blocks, power dividers, and directional couplers. Quasi-active units such as mixers, detectors, and frequency multipliers are also produced without PC boards. Active capabilities are achieved via external excitation. Many tubular components operating well into the microwave region do not use PC boards.



▲ **Figure 1. Highpass filter schematic.**

This article describes the design and construction of two filters, a 25 MHz cutoff highpass filter and a 70 MHz bandpass filter. The bandpass example includes a detailed description of the construction method.

Example 1 — A highpass filter

A relatively simple highpass filter has been designed, assembled, and tested as an illustrative example. This five pole highpass filter, with schematic per Figure 1, has been designed

Element	Value	Realization
L1, L5	0.326 μH	10 turns #26 AWG on T25-10 toroid
L3	0.156 μH	6 turns #26 AWG on T25-10 toroid
C2, C4	75 pF ±5%	CD15 dipped mica

▲ **Table 1: Highpass filter circuit element details.**

Frequency (MHz)	Loss (dB for Q_{UL} = 100)	Loss (dB Measured)
10	47.6	44.8
15	28.6	31.2
20	13.9	14.9
22.5	7.8	8.5
25	3.3	3.0
30	0.3	0.3
35	0.1	<0.1
40	0.085	<0.1
50	0.046	<0.1
75	0.025	0.3
100	0.02	0.6

▲ **Table 2. Highpass filter amplitude response.**

Element	Value	Realization
L (3 places)	0.200 μH	7 Turns #22 AWG on 1/4 inch dia. Solenoid
C (3 places)	0.8 to 10 pf	Johanson 5200 Series air capacitors
C1, C3	12 pF ±5 %	CD15 dipped mica fixed capacitor
C2	18 pF ±5%	CD15 dipped mica fixed capacitor
C01, C30	5.5 to 18 pF	Tusonix trimmer 538-000 A 5.5-18 pF
C12, C23	1.2 pF ±5 %	Quality Components ceramic cap. QC Series

▲ **Table 3. Bandpass filter circuit element details.**

for a nominal passband ripple of 0.01 dB and a 3-dB cut-off frequency of 25 MHz. Source and load impedances are 50 ohms. The circuit element values are shown in Table 1.

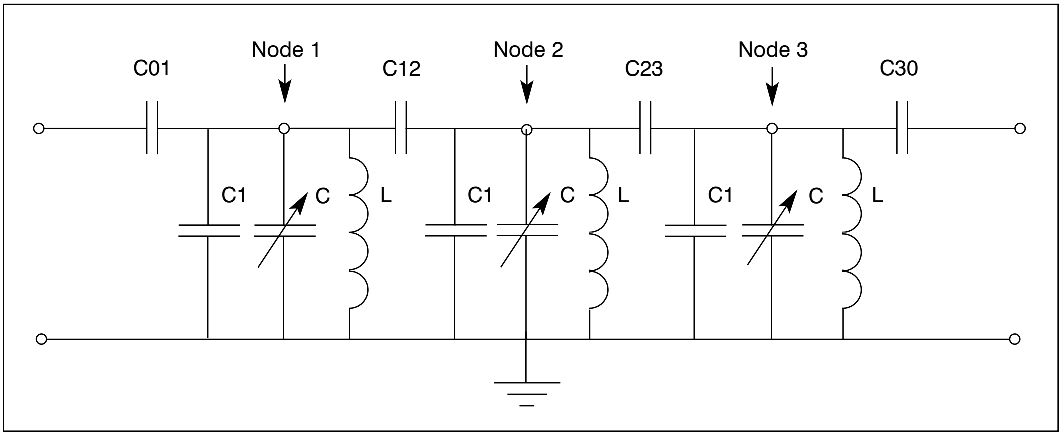
The high pass filter was constructed using one quarter inch diameter by one half inch long nylon spacers tapped for number 4-40 screw threads. Each spacer serves as mechanical support for a filter node. Spacer bottoms, with small grounded solder lugs, were secured to the enclosure using number 4-40 countersunk screws. Additional ungrounded solder lugs for each node connection were screwed to the top of the spacers. Inductive components were soldered between a nodal solder lug and ground. Leads from inductors L1 and L5 were extended and soldered directly to the input and output connectors. Capacitive components were soldered to adjacent nodal solder lugs. In solder assembly of the components, excessive heat must be avoided to keep from damaging the components. A twenty-five watt soldering iron is appropriate for the task. The enclosure used was a Pomona 2397 size A die cast aluminum box. Input and output connectors were Pomona 2451 BNC panel jacks.

Computed and measured amplitude responses for the high pass filter are shown in Table 2. The measured cut-off frequency is slightly below the 25 MHz design objective. At 75 and 100 MHz, measured data shows degradation, probably due to parasitic circuit elements such as capacitor lead inductance and inductor stray capacitance. Reasonable correlation was been obtained between theory and experiment using this method of construction.

Example 2 — VHF bandpass filter

The second directly-assembled circuit is a simple bandpass filter. Its design, assembly, and testing provides another useful example. This three-pole bandpass filter, with schematic per Figure 2, has been designed at the classic 70 MHz center frequency for a nominal passband ripple of 0.01 dB and a 3-dB bandwidth of 5 MHz. Source and load impedances are fifty ohms. The filter uses the familiar top-C coupled circuit with element values shown in Table 2.

The bandpass filter mechanical details are shown in Figure 3. Variable capacitors, for each of the three resonators, are fastened (grounded) to one side of the filter housing. Tuning adjustments are accessible outside the box permitting final adjustments with the cover secured to the box. Solenoid inductors are assembled on nylon coil forms as outlined in Figure 4. Each resonator inductor has the grounded end soldered to a lug which is screwed to the side of the filter enclosure at the coil form base. The ungrounded end of the

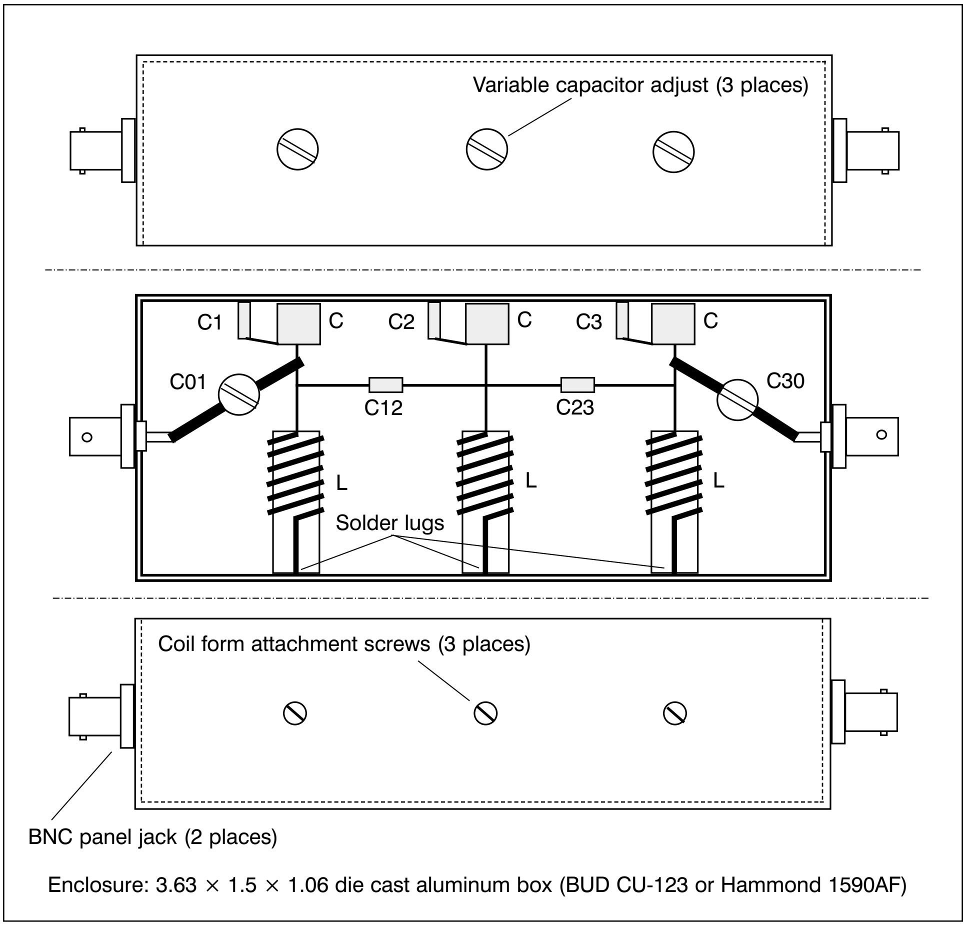


▲ **Figure 2. Schematic of the 70 MHz bandpass filter example.**

inductor is soldered to the floating (node) side of the variable capacitor to create each parallel resonant circuit. Fixed resonator capacitors C1, C2, and C3 are soldered across the variable capacitors from resonator nodes to ground.

Interstage coupling capacitors C12 and C23 are soldered between the adjacent resonator nodes. Filter input and output coupling capacitors C01 and C30 were soldered between the BNC connector center conductors and the first and third resonator nodes. Variable capacitors were used, which are adjusted with the cover removed.

The enclosure was a Bud Cu-123 or Hammond 1590 AF die cast aluminum box. Input and output connectors were Pomona 2451 BNC panel jacks. These items are readily available from many electronic component distributors.



▲ **Figure 3. Bandpass filter mechanical construction details.**

Fine adjustment of filter bandwidth can be achieved by spreading or squeezing turns of the magnet wire used to form the filter inductors. This permits small changes in inductance that alter filter interstage couplings. The Johanson 5200 series air variable capacitors used for tuning have been around for many years. Surplus parts are often available from old breadboards and prototypes, further reducing the cost of the filter. These capacitors could also be used for input and output couplings using JMC 6515 insulated adapters to fasten the floating variable capacitors to the housing. In that case, all filter final adjustments could be accessible outside the box with the cover on.

Measured amplitude response for the bandpass filter over ±10 MHz from the center frequency is shown in Table 2. The measured 70 MHz center frequency insertion loss was 1.5 dB. This corresponds to resonator unloaded Qs of 170. Filter skirt selectivity was sharper on the low frequency side than the high frequency side. This is expected for a band pass filter with all top-C couplings. These measurements show that reasonable performance has been obtained.

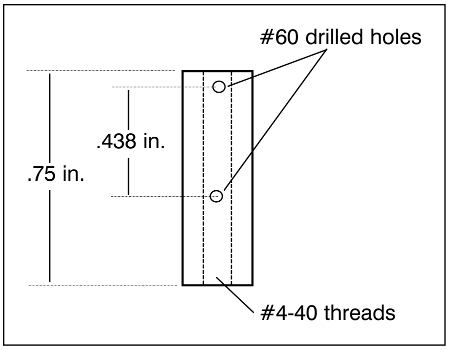
Other filter options

The three pole bandpass filter could also be realized with 75-five ohm input and output impedances using similar construction. This would be useful for CATV and other systems using this standard impedance.

If a 3-dB bandwidth of 10 MHz is desired, a five pole bandpass filter can be constructed in the same size

Frequency (MHz)	Relative Loss (dB)
60	41
65	19.5
67.5	4.0
68	1.8
68.5	0.9
69	0.4
69.5	0.15
70	0
70.5	0
71	0.3
71.5	1.0
72	2.5
72.5	4.4
75	15.5
80	29

▲ **Table 2. Measured relative amplitude response of the prototype bandpass filter.**



▲ **Figure 4. Preparation detail of the nylon spacer used as a coil form (three required).**

enclosure. This requires half inch physical spacings between adjacent resonators rather than the one inch spacings as in the three pole filter. As the filter percent bandwidth increases, peak fields become smaller and the effects of the filter cover and stray electromagnetic couplings are less significant.

This construction method can be used for many other filter configurations, as well as other L-C circuits such as diplexers and equalizers.

Summary

Realization of a highpass filter circuit and a simple bandpass filter circuit, without a PC board, has been demonstrated in this article. Engineering models will continue to fulfill their niche when standard filters are not suitable or not available. Commercial L-C and tubular bandpass filters, without PC boards, have been manufactured for many years but are not always available for stock delivery, or may not have the desired filter parameters..

Of course, the limited capability of this construction technique will not affect the ongoing use of surface mounted printed circuit boards in manufactured units. Ultimate realization of electronics hardware, designed for high volume production, will entail large scale integrated circuits at systems levels. ■

Author Information

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