SIMPLIFIED DESIGN OF LC BANDPASS FILTERS

Introduction

Long-time readers of ITEM are no doubt familiar with the tables of precalculated passive LC lowpass and highpass Chebyshev filter designs that appeared in previous issues of ITEM and other publications (1-8). These filter designs were unique in that they required only standard-value capicators. To use the tables, the 6 dB cutoff frequency column was scanned to find a design having a cutoff frequency closest to the desired cutoff frequency. The attenuation versus frequency and capacitor and inductor values were read from the table, thus eliminating the calculations usually associated with filter design and the accompanying chances for calculation error. Although the designs were based on 50 ohm equal terminations over the 1-10 MHz frequency decade, a simple impedance and frequency scaling procedure permitted designs to be obtained for any equal impedance termination or cutoff frequency while still keeping the advantage of standard-value capacitors (hereafter referred to as "SVC"). The design and construction of 7-element lowpass and highpass filters were considerably simplified with these SVC tables.

In addition to lowpass and highpass filters, the EMI/EMC engineer frequently needs to design bandpass filters. This filter type is required when a band of frequencies is to be passed to a detection system or receiver while attenuating undesired signals below and above the desired band of frequencies. Bandpass filters are also used with non-tunable detection systems to provide a specific 6 dB bandwidth to meet a test specification. Because of the frequent need for the bandpass filter, the EMI/EMC engineer should have available tables of precalculated SVC filter designs similar to those for the lowpass and highpass filter. This article will discuss such a design aid and present five tables of precalculated SVC bandpass filters.

Bandpass Filter Parameters

The important parameters defining the bandpass filter response are the upper and lower cutoff frequencies, the bandwidth, and the center frequency. Most EMI/EMC specifications use the 6 dB attenuation level to define the upper and lower cutoff frequencies, and this attenuation level is used in the discussion to follow. The 6 dB bandwidth (BW-6 dB) is the difference between the upper (F-up) and lower (F-lo) cutoff frequencies, and the center frequency (F-c) is the geometric mean of the upper and lower cutoff frequencies. That is:

$$\text{BW-6 dB} = (\text{F-up}) - (\text{F-lo}) \quad \text{and} \quad \text{F-c} = \sqrt{(\text{F-up})\,(\text{F-lo})}.$$

For example, if the 6 dB cutoff frequencies of a bandpass filter are 1 and 4 MHz, the 6 dB bandwidth is 3 MHz and the F-c is 2 MHz.

In addition to the upper and lower 6 dB cutoff frequencies having a geometric mean symmetry about the center frequency, the upper and lower frequencies at any attenuation level also have a geometric mean symmetry about the center frequency. Because of this characteristic, a plot of the attenuation versus frequency respose on a logarithmic frequency scale gives a response above the center frequency that is a mirror image of the response below the center frequency. This means that if the attenuation at a frequency equal to N times (F-c) is X dB, then the attenuation will be the same at (F-c) divided by N. For example, if the attenuation at two times the F-c is 28 dB, then the attenuation at half the center frequency will also be 28 dB.

The bandwidth of a bandpass filter is frequently stated in terms of percentage bandwidth, and it is equal to one hundred times the 6 dB bandwidth divided by the center frequency. That is, BW = 100%(BW)/(F-c). In the case of the previous bandpass filter example, the 6 dB percentage bandwidth is equal to 100%(4-1)/2 = 150%.

A bandpass filter response can be stated in the simplest terms of a center frequency and the 6 dB percentage bandwidth. The tables of bandpass filters presented in this article cover center frequencies between 1 and 10 MHz for approximate percentage bandwidths of 50 to 150% in increments of 25%. For those filter requirements where a percentage bandwidth greater than 150% is needed, a bandpass response is most easily obtained by cascading separate lowpass and highpass filters. If each filter sees its design impedance and if the separation of cutoff frequencies is greater than two octaves, the filters will perform as expected and there will be no significant undesired interaction between the filters. Each filter will see its design impedance looking into the other filter if the VSWR or reflection coefficient of each filter is low. For this reason, a reflection coefficient of less than 10% is recommended when cascading low and highpass filters. A reflection coefficient of 10% corresponds to a VSWR of 1.222. For bandwidths less than 150%, the standard lowpass to bandpass transformation is used. The bandpass filters presented in this article are based on this transformation procedure.

5-Element Lowpass Filter Transforms Into 5-Resonator Bandpass Filter

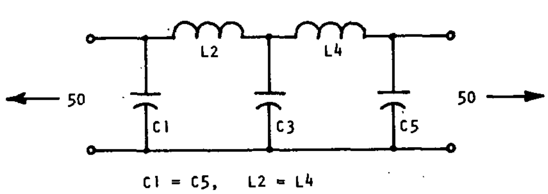
The standard procedure used in designing bandpass filters is to select a lowpass prototype filter having the proper characteristics, and then transform it into a bandpass filter. The relationship between the lowpass and bandpass responses is such that the bandwidth of the lowpass filter will be equal to the bandwidth of the transformed bandpass filter at any given attenuation level. Thus, to obtain a particular bandwidth, a lowpass prototype having a cutoff frequency equal to the desired bandwidth of the bandpass filter is selected. After performing the transformation procedure, the resulting bandpass filter will have a bandpass attentuation response with a bandwidth at any attenuation level equal to the bandwidth of the lowpass prototype filter at the same attenuation level. For example, if the attenuation level of the lowpass filter is 40 dB at one octave above the cutoff frequency (twice the cutoff frequency), then the 40 dB bandwidth of the transformed bandpass filter will be twice the bandwidth at the cutoff attenuation level.

Figure 1 shows the schematic diagram and typical response curve of the five-element lowpass filter used as the prototype. This lowpass filter is then transformed into a bandpass filter by resonating all inductors and capacitors to the desired center frequency of the bandpass filter. For example, to design a bandpass filter having a bandwidth of 3 MHz and a center frequency of 2 MHz, a 3 MHz lowpass filter is first selected. The low pass filter is then transformed into a bandpass filter having a 3 MHz bandwidth by resonating the capacitors and inductors with additional components to produce parallel and series resonant circuits is tuned to 2 MHz.

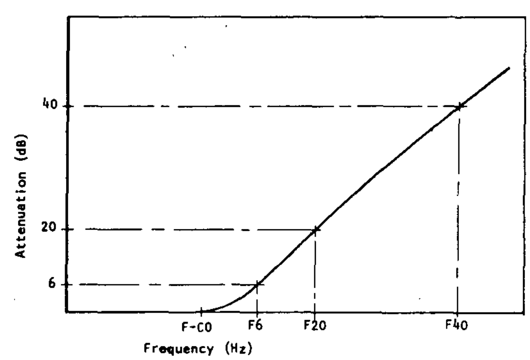
Figure 2 shows the bandpass filter configuration after the transformation procedure. Of course, the position of the resonant circuits in the bandpass filter configuration determines whether the circuit is series or parallel tuned. That is, if the resonant circuit is in shunt with the signal path, it will be parallel tuned, and if it is in series with the signal path, it will be series tuned. This is necessary so the center frequency can pass through the filter with minimum attenuation. If the alternate form of resonant circuits were used, that is, series instead of parallel and parallel instead of series, it can be seen that the configuration would function as a bandstop instead of a bandpass filter.

5-Element Lowpass Filter Designs Selected For Transformation

When selecting a lowpass filter for transformation into a bandpass filter, the professional filter designer usually picks a normalized design from tables published in several references (9-12). The normalized designs are then scaled to get a lowpass filter having the desired impedance level and cutoff frequency. Invariably, the capacitor values of both the lowpass prototype and the bandpass filter (after transformation from the lowpass design) will be non-standard, thus complicating the filter construction. To minimize cost and simplify construction, it is best if only SVC bandpass filter designs are used. For this reason, a table of 97 precalculated SVC 5-element 50 ohm lowpass Chebshev filter designs was prepared for use in the bandpass filter transformation. Table 1 shows the SVC designs selected for transformation. Chebyshev lowpass designs for the SVC bandpass tables were selected with reflection coefficients between 1% and 15% to minimize VSWR and passband attenuation ripple. The VSWR and maximum passband attenuation corresponding to a reflection coefficient of 15% are 1.353 and .09883 db, respectively.



(A) Schematic diagram.



(B) Typical attenuation response.

Figure 1. 5-Element Chebyshev Lowpass Filter.

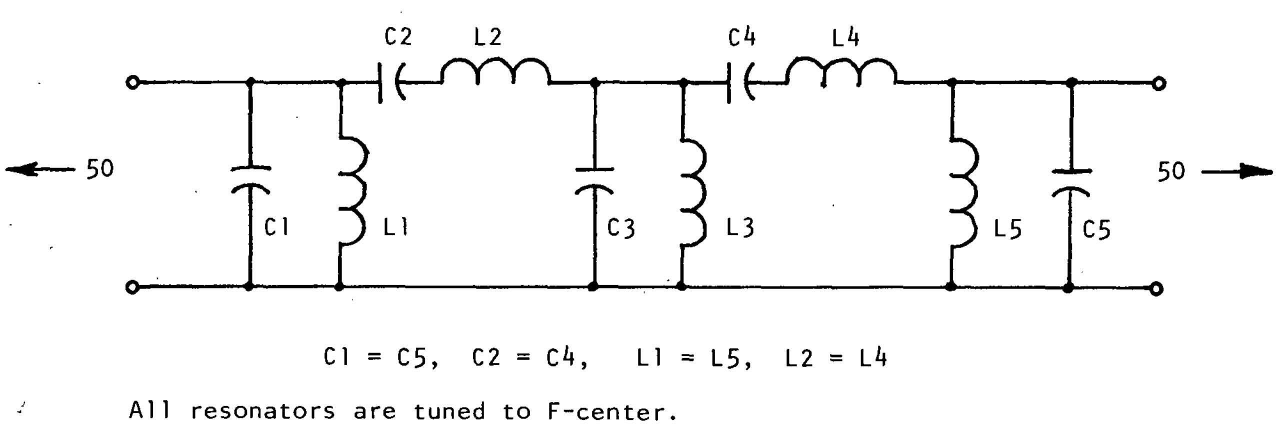


Figure 2. 5-Resonator Chebyshev Bandpass Filter Schematic Diagram.

NO.	-------FREQUENCY (MHZ)-------				R.C.	C1,5	L2,4	C3
	F-CO	6-DB	20-DB	40-DB	(%)	(PF)	(UH)	(PF)
1	1.016	1.288	1.651	2.452	9.58	3000	10.73	5600
2	1.101	1.407	1.808	2.689	8.93	2700	9.882	5100
3	1.039	1.477	1.944	2.940	4.06	2200	9.818	4700
4	1.146	1.507	1.950	2.916	7.19	2400	9.373	4700
5	1.319	1.594	2.014	2.959	14.22	2700	8.289	4700
6	1.127	1.613	2.125	3.216	3.88	2000	9.003	4300
7	1.256	1.648	2.132	3.187	7.27	2200	8.564	4300
8	1.390	1.712	2.176	3.212	12.11	2400	7.881	4300
9	1.054	1.764	2.379	3.656	1.39	1600	8.351	3900
10	1.232	1.776	2.344	3.551	3.67	1800	8.187	3900
11	1.388	1.819	2.352	3.514	7.38	2000	7.754	3900
12	1.553	1.899	2.408	3.549	12.85	2200	7.053	3900
13	1.169	1.911	2.570	3.942	1.60	1500	7.703	3600
14	1.275	1.916	2.547	3.876	2.77	1600	7.635	3600
15	1.462	1.955	2.541	3.810	6.30	1800	7.281	3600
16	1.650	2.039	2.594	3.833	11.80	2000	6.635	3600
17	1.430	2.095	2.773	4.209	3.29	1500	6.960	3300
18	1.541	2.117	2.768	4.167	5.16	1600	6.789	3300
19	1.761	2.204	2.814	4.169	10.63	1800	6.210	3300
20	1.315	2.294	3.108	4.791	1.07	1200	6.424	3000
21	1.481	2.296	3.065	4.680	2.26	1300	6.393	3000
22	1.754	2.346	3.049	4.572	6.30	1500	6.067	3000
23	1.887	2.399	3.078	4.574	9.33	1600	5.773	3000
24	1.506	2.548	3.440	5.292	1.29	1100	5.782	2700
25	1.700	2.555	3.395	5.169	2.77	1200	5.726	2700
26	1.868	2.584	3.382	5.097	4.93	1300	5.573	2700
27	2.201	2.719	3.459	5.110	11.80	1500	4.976	2700
28	1.753	2.866	3.854	5.913	1.60	1000	5.135	2400
29	1.965	2.884	3.810	5.778	3.49	1100	5.049	2400
30	2.193	2.933	3.811	5.715	6.30	1200	4.854	2400
31	2.402	3.020	3.862	5.727	10.21	1300	4.549	2400
32	1.892	3.126	4.210	6.465	1.50	910	4.709	2200
33	2.145	3.143	4.159	6.313	3.29	1000	4.640	2200
34	2.392	3.200	4.158	6.235	6.30	1100	4.449	2200
35	2.642	3.305	4.221	6.253	10.63	1200	4.140	2200
36	2.053	3.439	4.639	7.130	1.38	820	4.283	2000
37	2.362	3.457	4.574	6.943	3.31	910	4.217	2000
38	2.631	3.520	4.574	6.858	6.30	1000	4.045	2000
39	2.935	3.651	4.655	6.887	11.14	1100	3.729	2000
40	2.338	3.821	5.139	7.884	1.60	750	3.851	1800
41	2.628	3.842	5.082	7.713	3.34	820	3.794	1800
42	2.960	3.923	5.087	7.616	6.76	910	3.614	1800
43	3.301	4.079	5.189	7.665	11.80	1000	3.317	1800
44	2.705	4.301	5.763	8.820	1.92	680	3.418	1600
45	3.058	4.339	5.709	8.633	4.10	750	3.340	1600
46	3.381	4.432	5.732	8.566	7.35	820	3.182	1600
47	3.824	4.652	5.889	8.669	13.46	910	2.862	1600
48	2.772	4.586	6.176	9.483	1.49	620	3.211	1500
49	3.135	4.608	6.101	9.264	3.22	680	3.166	1500
50	3.508	4.693	6.098	9.144	6.30	750	3.033	1500
51	3.885	4.853	6.195	9.174	10.76	820	2.816	1500
52	3.391	5.296	7.079	10.82	2.15	560	2.772	1300
53	3.838	5.357	7.024	10.60	4.62	620	2.695	1300
54	4.259	5.494	7.076	10.54	8.32	680	2.545	1300
55	4.794	5.780	7.295	10.71	14.56	750	2.278	1300
56	3.607	5.734	7.684	11.76	1.92	510	2.563	1200
57	4.056	5.782	7.613	11.52	3.98	560	2.509	1200
58	4.550	5.926	7.651	11.42	7.72	620	2.372	1200
59	5.075	6.189	7.841	11.55	13.18	680	2.157	1200
60	3.963	6.257	8.375	12.81	2.01	470	2.348	1100
61	4.391	6.301	8.308	12.58	3.80	510	2.305	1100
62	4.881	6.433	8.330	12.46	7.05	560	2.198	1100
63	5.499	6.730	8.535	12.58	12.80	620	1.991	1100
64	4.398	6.884	9.204	14.07	2.12	430	2.133	1000
65	4.907	6.946	9.134	13.81	4.18	470	2.085	1000
66	5.380	7.080	9.165	13.71	7.13	510	1.996	1000
67	6.000	7.374	9.366	13.82	12.34	560	1.825	1000
68	4.811	7.564	10.12	15.47	2.06	390	1.942	910
69	5.426	7.640	10.04	15.16	4.34	430	1.894	910
70	5.997	7.813	10.09	15.06	7.70	470	1.799	910
71	6.600	8.108	10.30	15.19	12.39	510	1.659	910
72	4.862	8.391	11.36	17.49	1.14	330	1.756	820
73	5.511	8.405	11.19	17.07	2.51	360	1.743	820
74	6.066	8.488	11.14	16.81	4.54	390	1.702	820
75	6.771	8.718	11.22	16.72	8.44	430	1.602	820
76	7.536	9.123	11.53	16.95	14.05	470	1.451	820
77	5.262	9.175	12.43	19.16	1.07	300	1.606	750
78	6.042	9.191	12.24	18.65	2.56	330	1.594	750
79	6.702	9.296	12.18	18.36	4.83	360	1.550	750
80	7.332	9.502	12.25	18.27	8.03	390	1.475	750
81	8.243	9.977	12.61	18.54	14.07	430	1.326	750
82	6.687	10.14	13.49	20.56	2.61	300	1.444	680
83	7.484	10.28	13.43	20.22	5.20	330	1.398	680
84	8.254	10.55	13.56	20.17	8.93	360	1.317	680
85	9.095	11.01	13.91	20.45	14.09	390	1.202	680
86	7.213	11.11	14.82	22.62	2.35	270	1.320	620
87	8.181	11.26	14.73	22.18	5.10	300	1.276	620
88	9.109	11.60	14.89	22.13	9.22	330	1.195	620
89	7.818	12.29	16.44	25.14	2.06	240	1.195	560
90	9.021	12.46	16.31	24.57	4.98	270	1.155	560
91	10.16	12.88	16.51	24.52	9.58	300	1.073	560
92	8.659	13.50	18.04	27.56	2.17	220	1.087	510
93	9.636	13.62	17.91	27.07	4.22	240	1.063	510
94	9.224	14.64	19.61	30.02	1.94	200	1.003	470
95	10.39	14.77	19.44	29.40	4.06	220	.981	470
96	9.851	16.00	21.50	32.96	1.67	180	.919	430
97	10.54	17.64	23.79	36.56	1.39	160	.835	390

Table 1. 5-Element, 50-Ohm, Low-Pass Chebyshev SVC-Filter Designs, Capacitive Input, 5% Capacitor Tolerance, Selected Maximum R.C. = 15%.

A lowpass filter of five elements was chosen for transformation to a bandpass filter. After transformation, the resulting bandpass filter consists of five capacitors and five inductors. This number of elements was considered to be a suitable compromise between complexity and selectivity of the final bandpass filter. The bandpass filter skirt selectivity at the 6 dB cutoff frequency is greater than 45 dB per octave, and the 40/6 dB shape factor is less than 2.2.

Bandpass Filter Parameters Selected for Tabulation

As previously explained, the two primary parameters of the bandpass filter are center frequency and percentage bandwidth. These two parameters were used to select the tables of precalculated bandpass designs. Each table of bandpass designs was tabulated for a specific bandwidth percentage and for twenty-five pairs of center frequencies starting at 1 MHz and increasing in approximate increments of 10% to 10 MHz. These center frequency increments are considered small enough to allow the close approximation of virtually any desired center frequency. Tables 2, 3, 4, 5 and 6 represent close approximations to percentage bandwidths of 50% to 150% in increments of 25%. These bandwidth increments are considered small enough so that the bandwidth requirements of most test specifications can be met. All designs are based on 50 ohm equal terminations and standard-value capacitors. The center frequency and the 6 dB bandwidth of each filter design is tabulated along with the frequencies at the 3, 6, 20 and 40 dB attenuation levels. These data allow the user to approximate the filter response by plotting it on semi-log graph paper. Figure 3 shows three typical bandpass filter responses for a design having a reflection coefficient of 6.3% and bandwidth percentages of 50, 100 and 150 percent based on a normalized center frequency of one. The responses for bandwidth percentages of 75 and 125% can be interpolated between the adjacent responses. Note that the lower frequencies are the reciprocals of the upper frequencies at the same attenuation level. The frequency data in Tables 2 through 6 will demonstrate a similar relationship if all the frequencies are first normalized to a center frequency of unity.

How to Use the Bandpass Filter Design Tables

For 50 ohm Filters. In order to use the bandpass filter design tables, design requirements must be stated in terms of percentage bandwidth and center frequency. Assuming a 50 ohm bandpass filter is desired with lower and upper 6 dB cutoff frequencies of 1 and 4 MHz, the percentage bandwidth and center frequency are 150% and 2 MHz. Table 6 (for 150% bandwidth) is scanned for the F-c column for a frequency closest to the desired 2 MHz F-c. In this case, designs 15 and 16 straddle the desired value. Both designs have a reflection coefficient of 10.21% which will be suitable for most applications. The 6 dB BW column shows that the bandwidth of these two designs is within 1% of the desired 3 MHz bandwidth. C1,5 and C2,4 all have the same standard value of 1300 pF. Either design No. 15 or 16 may be used, but design No. 16 may be more convenient to construct because of the duplication of the 1300 pF capacitor value.

The prototype lowpass design on which bandpass designs 15 and 16 are based may be found by noting the C1,5 and C3 values, or the 6 dB BW, and then searching Table 1 for the same values. In this case, lowpass design No. 31 was the prototype upon which bandpass designs 15 and 16 were based. There are two bandpass designs for each lowpass design because the calculation procedure provides a bandpass design on either side of the selected center frequency.

When the desired percentage bandwidth is different from the the table values, a design from one of the tables having a percentage bandwidth closest to the desired value must be selected. The EMI/EMC bandwidth test specifications are usually lenient enough to permit the actual bandwidth to vary up to 20% from the specified bandwidth. The same procedure is used when searching for a suitable center frequency.

Although the tables are arranged for center frequencies of 1 to 10 MHz, it is possible to scale the data by inspection to other frequency decades by shifting the decimal points to the right or left. To find data for the 10-100 or 100-1000 MHz decades all tabulated frequencies are multiplied by 10 or 100, respectively, and all C and L values are divided by the same number. The reflection coefficients remain unchanged. To scale the filter tables to cover the 1-10 kHz, 10-100 kHz or .1-1 Mhz decades, the tabulated frequencies are divided by 1000, 100 or 10, respectively, and the component values are multiplied by the same number. For example, the tables are easily changed from the 1-10 MHz range to the 1-10 kHz range by changing the frequency headings in MHz to kHz, and the capacitor and inductor headings in pF and μH to nF and mH, where 1 nF = 1000 pF and 1 mH = 1000 μH. By mentally changing the column headings, the table values may be read directly for the 1-10 kHz frequency range. The impedance level remains at 50 ohms.

For Impedance Levels Other Than 50 Ohms. All tabulated bandpass designs can be scaled to impedance levels other than 50 ohms with a simple scaling procedure while maintaining the advantage of standard-value capacitors. If the impedance level differs from 50 ohms by a factor equal to an integral power of 10 (such as .1, 10 or 100), the design tables are scaled by shifting the decimals of the component values. The frequencies and reflection coefficient values remain unchanged. For example, if the 50 ohm impedance level is raised by a factor of 10 to 500 ohms, the tabulated capacitance and inductance values are scaled to 500 ohms by dividing the capacitor values by 10, and by multiplying the inductance values by 10. The reverse is true if the impedance level is lowered from 50 to 5 ohms.

For impedance levels differing from the standard 50 ohms by a factor equal to a non-integral power of 10 (such as 1.2 or 1.5), the following scaling procedure is used:

1. The impedance scaling factor is calculated, $R = Zx/50$ where Zx is the desired new impedance level in ohms.

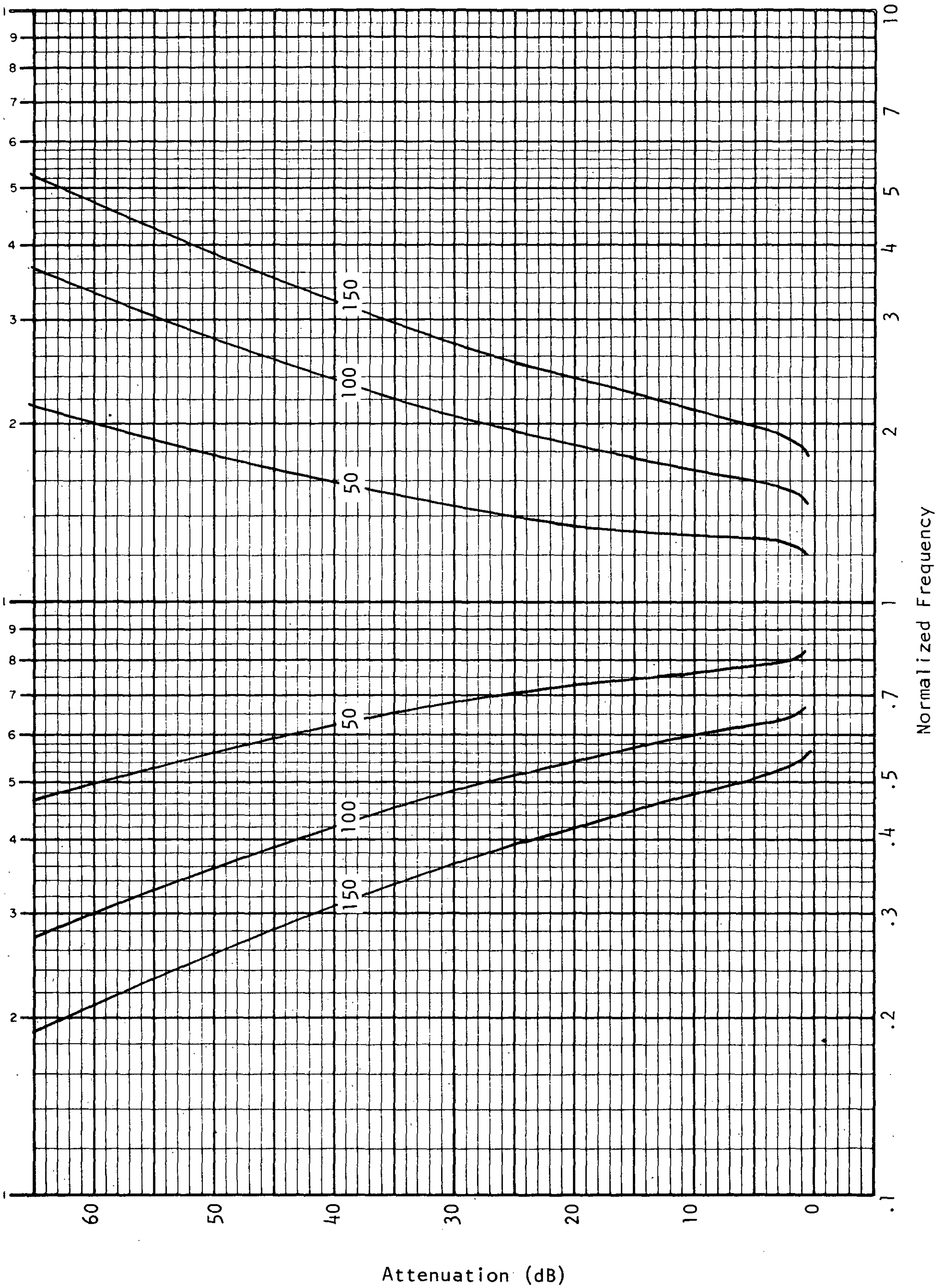


Figure 3. Typical Bandpass Filter Responses for Percentage Bandwidths of 50, 100 and 150%, R.C. = 6.3%.

DESIGN NO.	F-C (MHZ)	6-DB BW (MHZ)	40	20	6	3	3	6	20	40	R.C. (%)	C1,5 (PF)	C2,4 (PF)	C3 (PF)	L1,5 (UH)	L2,4 (UH)	L3 (UH)
			----------- ATTENUATION LEVELS (DB) -----------														
			----(LOWER RANGE)---(MHZ)---(UPPER RANGE)----														
1	.9942	.4853	.636	.732	.781	.792	1.25	1.27	1.35	1.55	10.76	8200	910	15 K	3.13	28.2	1.71
2	1.047	.4853	.685	.782	.832	.844	1.30	1.32	1.40	1.60	10.76	8200	820	15 K	2.82	28.2	1.54
3	1.046	.5494	.644	.750	.807	.820	1.33	1.36	1.46	1.70	8.32	6800	910	13 K	3.41	25.5	1.78
4	1.102	.5494	.694	.803	.861	.874	1.39	1.41	1.51	1.75	8.32	6800	820	13 K	3.07	25.5	1.61
5	1.193	.5926	.752	.870	.933	.948	1.50	1.53	1.64	1.89	7.72	6200	750	12 K	2.87	23.7	1.48
6	1.253	.5926	.806	.928	.991	1.01	1.56	1.58	1.69	1.95	7.72	6200	680	12 K	2.60	23.7	1.34
7	1.239	.6433	.764	.891	.959	.975	1.58	1.60	1.72	2.01	7.05	5600	750	11 K	2.94	22.0	1.50
8	1.302	.6433	.820	.950	1.02	1.04	1.64	1.66	1.78	2.07	7.05	5600	680	11 K	2.67	22.0	1.36
9	1.429	.7375	.896	1.04	1.11	1.12	1.82	1.84	1.97	2.28	12.34	5600	680	10 K	2.22	18.3	1.24
10	1.496	.7375	.957	1.10	1.17	1.19	1.88	1.91	2.04	2.34	12.34	5600	620	10 K	2.02	18.3	1.13
11	1.569	.8108	.984	1.14	1.22	1.23	2.00	2.03	2.17	2.50	12.39	5100	620	9100	2.02	16.6	1.13
12	1.651	.8108	1.06	1.21	1.29	1.31	2.08	2.11	2.24	2.58	12.39	5100	560	9100	1.82	16.6	1.02
13	1.766	.9123	1.11	1.28	1.37	1.39	2.25	2.28	2.43	2.81	14.05	4700	560	8200	1.73	14.5	.991
14	1.850	.9123	1.19	1.36	1.45	1.47	2.33	2.36	2.51	2.88	14.05	4700	510	8200	1.57	14.5	.902
15	1.935	.9977	1.22	1.40	1.50	1.52	2.46	2.50	2.67	3.07	14.07	4300	510	7500	1.57	13.3	.902
16	2.016	.9977	1.29	1.48	1.58	1.60	2.54	2.58	2.74	3.15	14.07	4300	470	7500	1.45	13.3	.831
17	2.114	1.055	1.33	1.54	1.65	1.68	2.67	2.71	2.90	3.35	8.93	3600	430	6800	1.57	13.2	.833
18	2.220	1.055	1.43	1.64	1.75	1.78	2.77	2.81	3.00	3.45	8.93	3600	390	6800	1.43	13.2	.756
19	2.331	1.160	1.47	1.70	1.82	1.85	2.94	2.98	3.19	3.69	9.22	3300	390	6200	1.41	12.0	.752
20	2.426	1.160	1.56	1.79	1.91	1.94	3.03	3.07	3.28	3.77	9.22	3300	360	6200	1.30	12.0	.694
21	2.560	1.288	1.61	1.86	2.00	2.03	3.24	3.28	3.52	4.06	9.58	3000	360	5600	1.29	10.7	.690
22	2.674	1.288	1.72	1.97	2.11	2.14	3.35	3.39	3.62	4.17	9.58	3000	330	5600	1.18	10.7	.632
23	2.796	1.477	1.69	1.99	2.15	2.19	3.56	3.63	3.93	4.63	4.06	2200	330	4700	1.47	9.82	.689
24	2.933	1.477	1.81	2.12	2.29	2.33	3.70	3.76	4.06	4.75	4.06	2200	300	4700	1.34	9.82	.627
25	2.862	1.507	1.75	2.05	2.21	2.24	3.65	3.71	4.00	4.67	7.19	2400	330	4700	1.29	9.37	.658
26	3.001	1.507	1.88	2.18	2.34	2.38	3.79	3.85	4.13	4.79	7.19	2400	300	4700	1.17	9.37	.598
27	3.140	1.648	1.93	2.25	2.42	2.46	4.00	4.07	4.38	5.11	7.27	2200	300	4300	1.17	8.56	.598
28	3.310	1.648	2.08	2.41	2.59	2.63	4.17	4.23	4.54	5.27	7.27	2200	270	4300	1.05	8.56	.538
29	3.478	1.819	2.14	2.50	2.69	2.73	4.43	4.50	4.85	5.65	7.38	2000	270	3900	1.05	7.75	.537
30	3.689	1.819	2.33	2.70	2.89	2.94	4.64	4.71	5.05	5.84	7.38	2000	240	3900	.931	7.75	.477
31	3.977	1.955	2.50	2.90	3.12	3.17	4.99	5.07	5.45	6.31	6.30	1800	220	3600	.890	7.28	.445
32	4.171	1.955	2.68	3.09	3.31	3.36	5.18	5.26	5.63	6.49	6.30	1800	200	3600	.809	7.28	.405
33	4.306	2.204	2.70	3.12	3.34	3.39	5.46	5.55	5.94	6.87	10.63	1800	220	3300	.759	6.21	.414
34	4.516	2.204	2.89	3.32	3.55	3.60	5.67	5.75	6.14	7.06	10.63	1800	200	3300	.690	6.21	.376
35	4.683	2.399	2.92	3.39	3.64	3.69	5.94	6.03	6.47	7.50	9.33	1600	200	3000	.722	5.77	.385
36	4.937	2.399	3.15	3.63	3.88	3.94	6.19	6.28	6.71	7.73	9.33	1600	180	3000	.650	5.77	.346
37	5.045	2.719	3.10	3.60	3.87	3.92	6.48	6.58	7.06	8.21	11.80	1500	200	2700	.664	4.98	.369
38	5.318	2.719	3.34	3.86	4.13	4.19	6.75	6.85	7.32	8.45	11.80	1500	180	2700	.597	4.98	.332
39	5.783	2.884	3.58	4.18	4.52	4.60	7.27	7.40	7.99	9.35	3.49	1100	150	2400	.689	5.05	.316
40	6.212	2.884	3.96	4.59	4.94	5.02	7.69	7.82	8.40	9.74	3.49	1100	130	2400	.597	5.05	.274
41	6.160	3.200	3.79	4.42	4.76	4.85	7.83	7.96	8.58	10.0	6.30	1100	150	2200	.607	4.45	.303
42	6.617	3.200	4.20	4.86	5.21	5.29	8.28	8.41	9.02	10.4	6.30	1100	130	2200	.526	4.45	.263
43	6.940	3.520	4.31	5.02	5.40	5.49	8.77	8.92	9.59	11.2	6.30	1000	130	2000	.526	4.05	.263
44	7.224	3.520	4.57	5.29	5.68	5.77	9.05	9.19	9.86	11.4	6.30	1000	120	2000	.485	4.05	.243
45	7.459	3.842	4.54	5.34	5.78	5.89	9.45	9.62	10.4	12.3	3.34	820	120	1800	.555	3.79	.253
46	7.791	3.842	4.84	5.65	6.10	6.21	9.77	9.95	10.7	12.5	3.34	820	110	1800	.509	3.79	.232
47	8.208	4.301	4.91	5.82	6.33	6.46	10.42	10.6	11.6	13.7	1.92	680	110	1600	.553	3.42	.235
48	8.608	4.301	5.26	6.20	6.72	6.85	10.81	11.0	12.0	14.1	1.92	680	100	1600	.503	3.42	.214
49	8.945	4.608	5.44	6.40	6.93	7.06	11.33	11.5	12.5	14.7	3.22	680	100	1500	.466	3.17	.211
50	9.377	4.608	5.83	6.81	7.35	7.48	11.75	12.0	12.9	15.1	3.22	680	91	1500	.424	3.17	.192

Table 2. 5th-Degree, 50-Ohm Chebyshev Bandpass Filters Using Standard-Value Capacitors for 6-dB Percentage Bandwidth = Approx. 50%.

DESIGN NO.	F-C (MHZ)	6-DB BW (MHZ)	ATTENUATION LEVELS (DB) 40	20	6	3	3	6	20	40	R.C. (%)	C1,5 (PF)	C2,4 (PF)	C3 (PF)	L1,5 (UH)	L2,4 (UH)	L3 (UH)
			(LOWER RANGE)			(MHZ)			(UPPER RANGE)								
1	.9324	.7564	.438	.555	.628	.647	1.34	1.38	1.57	1.99	2.06	3900	1500	9100	7.47	19.4	3.20
2	1.002	.7564	.492	.616	.692	.712	1.41	1.45	1.63	2.04	2.06	3900	1300	9100	6.47	19.4	2.77
3	1.084	.8108	.564	.685	.752	.767	1.53	1.56	1.71	2.08	12.39	5100	1300	9100	4.23	16.6	2.37
4	1.128	.8108	.600	.725	.793	.809	1.57	1.60	1.75	2.12	12.39	5100	1200	9100	3.90	16.6	2.19
5	1.197	.9176	.575	.728	.823	.849	1.69	1.74	1.97	2.49	1.07	3000	1100	7500	5.89	16.1	2.36
6	1.256	.9176	.621	.780	.878	.904	1.74	1.80	2.02	2.54	1.07	3000	1000	7500	5.35	16.1	2.14
7	1.249	.9503	.634	.779	.861	.881	1.77	1.81	2.00	2.46	8.03	3900	1100	7500	4.16	14.8	2.16
8	1.310	.9503	.684	.834	.919	.939	1.83	1.87	2.06	2.51	8.03	3900	1000	7500	3.78	14.8	1.97
9	1.387	1.055	.706	.865	.956	.977	1.97	2.01	2.22	2.72	8.93	3600	1000	6800	3.66	13.2	1.94
10	1.453	1.055	.761	.926	1.02	1.04	2.03	2.07	2.28	2.78	8.93	3600	910	6800	3.33	13.2	1.76
11	1.526	1.229	.720	.911	1.03	1.06	2.19	2.26	2.56	3.23	2.06	2400	910	5600	4.53	12.0	1.94
12	1.608	1.229	.784	.983	1.11	1.14	2.27	2.34	2.63	3.30	2.06	2400	820	5600	4.08	12.0	1.75
13	1.762	1.350	.859	1.08	1.21	1.25	2.49	2.56	2.88	3.62	2.17	2200	750	5100	3.71	10.9	1.60
14	1.851	1.350	.929	1.16	1.29	1.33	2.57	2.65	2.96	3.69	2.17	2200	680	5100	3.36	10.9	1.45
15	1.993	1.507	1.01	1.24	1.38	1.41	2.82	2.88	3.19	3.93	7.19	2400	680	4700	2.66	9.37	1.36
16	2.088	1.507	1.09	1.33	1.47	1.50	2.91	2.97	3.28	4.00	7.19	2400	620	4700	2.42	9.37	1.24
17	2.130	1.613	1.06	1.32	1.47	1.51	3.01	3.08	3.44	4.28	3.88	2000	620	4300	2.79	9.00	1.30
18	2.241	1.613	1.15	1.42	1.58	1.61	3.11	3.19	3.54	4.37	3.88	2000	560	4300	2.52	9.00	1.17
19	2.327	1.764	1.13	1.42	1.61	1.65	3.27	3.37	3.80	4.79	1.39	1600	560	3900	2.92	8.35	1.20
20	2.439	1.764	1.22	1.52	1.71	1.76	3.38	3.48	3.90	4.88	1.39	1600	510	3900	2.66	8.35	1.09
21	2.492	1.955	1.23	1.53	1.70	1.74	3.57	3.66	4.07	5.04	6.30	1800	560	3600	2.27	7.28	1.13
22	2.612	1.955	1.33	1.63	1.81	1.85	3.68	3.77	4.17	5.14	6.30	1800	510	3600	2.06	7.28	1.03
23	2.817	2.117	1.42	1.76	1.95	2.00	3.97	4.07	4.52	5.59	5.16	1600	470	3300	1.99	6.79	.967
24	2.946	2.117	1.52	1.87	2.07	2.12	4.09	4.19	4.64	5.69	5.16	1600	430	3300	1.82	6.79	.885
25	2.946	2.204	1.52	1.86	2.04	2.09	4.16	4.25	4.67	5.69	10.63	1800	470	3300	1.62	6.21	.884
26	3.080	2.204	1.63	1.98	2.17	2.21	4.29	4.37	4.79	5.80	10.63	1800	430	3300	1.48	6.21	.809
27	3.192	2.548	1.50	1.91	2.16	2.23	4.57	4.71	5.35	6.79	1.29	1100	430	2700	2.26	5.78	.921
28	3.351	2.548	1.62	2.05	2.31	2.38	4.72	4.86	5.49	6.92	1.29	1100	390	2700	2.05	5.78	.835
29	3.613	2.719	1.87	2.28	2.50	2.55	5.11	5.22	5.73	6.98	11.80	1500	390	2700	1.29	4.98	.719
30	3.760	2.719	1.99	2.41	2.64	2.69	5.25	5.36	5.87	7.10	11.80	1500	360	2700	1.19	4.98	.664
31	3.933	3.020	2.00	2.45	2.70	2.76	5.60	5.72	6.31	7.73	10.21	1300	360	2400	1.26	4.55	.682
32	4.108	3.020	2.14	2.61	2.87	2.93	5.76	5.89	6.47	7.87	10.21	1300	330	2400	1.15	4.55	.626
33	4.306	3.306	2.19	2.68	2.96	3.02	6.13	6.26	6.91	8.45	10.63	1200	330	2200	1.14	4.14	.621
34	4.516	3.306	2.37	2.87	3.16	3.22	6.33	6.46	7.10	8.62	10.63	1200	300	2200	1.04	4.14	.565
35	4.758	3.651	2.43	2.97	3.27	3.34	6.78	6.92	7.62	9.32	11.14	1100	300	2000	1.02	3.73	.559
36	5.015	3.651	2.64	3.20	3.51	3.58	7.02	7.16	7.86	9.53	11.14	1100	270	2000	.915	3.73	.503
37	5.094	3.923	2.55	3.15	3.50	3.58	7.25	7.42	8.24	10.2	6.76	910	270	1800	1.07	3.61	.542
38	5.403	3.923	2.80	3.43	3.79	3.87	7.54	7.71	8.52	10.4	6.76	910	240	1800	.953	3.61	.482
39	5.621	4.339	2.77	3.45	3.86	3.96	7.98	8.19	9.16	11.4	4.10	750	240	1600	1.07	3.34	.501
40	5.871	4.339	2.97	3.67	4.09	4.19	8.22	8.43	9.38	11.6	4.10	750	220	1600	.980	3.34	.459
41	6.394	4.853	3.28	4.01	4.41	4.51	9.07	9.27	10.2	12.5	10.76	820	220	1500	.756	2.82	.413
42	6.706	4.853	3.54	4.29	4.71	4.80	9.37	9.56	10.5	12.7	10.76	820	200	1500	.687	2.82	.375
43	6.759	5.296	3.25	4.09	4.61	4.74	9.63	9.91	11.2	14.1	2.15	560	200	1300	.990	2.77	.427
44	7.124	5.296	3.54	4.42	4.95	5.09	9.97	10.2	11.5	14.4	2.15	560	180	1300	.891	2.77	.384
45	7.455	5.780	3.82	4.65	5.11	5.21	10.67	10.9	11.9	14.5	14.56	750	200	1300	.608	2.28	.351
46	7.859	5.780	4.15	5.02	5.48	5.59	11.05	11.3	12.3	14.9	14.56	750	180	1300	.547	2.28	.315
47	8.286	6.301	4.11	5.12	5.71	5.86	11.71	12.0	13.4	16.7	3.80	510	160	1100	.723	2.31	.335
48	8.558	6.301	4.33	5.36	5.97	6.12	11.97	12.3	13.7	16.9	3.80	510	150	1100	.678	2.31	.314
49	8.998	6.946	4.44	5.52	6.17	6.33	12.78	13.1	14.7	18.2	4.18	470	150	1000	.666	2.09	.313
50	9.665	6.946	4.97	6.12	6.80	6.96	13.41	13.7	15.3	18.8	4.18	470	130	1000	.577	2.09	.271

Table 3. 5th-Degree, 50-Ohm Chebyshev Bandpass Filters Using Standard-Value Capacitors for 6-dB Percentage Bandwidth = Approx. 75%.

			ATTENUATION LEVELS (DB)														
DESIGN NO.	F-C (MHZ)	6-DB BW (MHZ)	40	20	6	3	3	6	20	40	R.C. (%)	C1,5 (PF)	C2,4 (PF)	C3 (PF)	L1,5 (UH)	L2,4 (UH)	L3 (UH)
			(LOWER RANGE)			(MHZ)		(UPPER RANGE)									
1	.9771	.9977	.420	.532	.598	.614	1.56	1.60	1.79	2.27	14.07	4300	2000	7500	6.17	13.3	3.54
2	1.030	.9977	.459	.577	.646	.662	1.60	1.64	1.84	2.31	14.07	4300	1800	7500	5.55	13.3	3.18
3	1.082	1.101	.466	.591	.664	.681	1.72	1.76	1.98	2.51	14.09	3900	1800	6800	5.55	12.0	3.18
4	1.148	1.101	.515	.646	.722	.740	1.78	1.82	2.04	2.56	14.09	3900	1600	6800	4.93	12.0	2.83
5	1.189	1.229	.473	.623	.724	.750	1.88	1.95	2.27	2.99	2.06	2400	1500	5600	7.47	12.0	3.20
6	1.277	1.229	.535	.696	.802	.830	1.96	2.03	2.34	3.05	2.06	2400	1300	5600	6.47	12.0	2.77
7	1.254	1.288	.528	.676	.766	.788	2.00	2.05	2.33	2.98	9.58	3000	1500	5600	5.37	10.7	2.87
8	1.347	1.288	.596	.755	.849	.872	2.08	2.14	2.41	3.05	9.58	3000	1300	5600	4.65	10.7	2.49
9	1.393	1.464	.547	.723	.842	.873	2.22	2.31	2.68	3.55	1.94	2000	1300	4700	6.53	10.0	2.78
10	1.450	1.464	.586	.770	.892	.925	2.27	2.36	2.73	3.59	1.94	2000	1200	4700	6.02	10.0	2.56
11	1.582	1.600	.637	.838	.973	1.01	2.48	2.57	2.99	3.93	1.67	1800	1100	4300	5.62	9.20	2.35
12	1.659	1.600	.691	.902	1.04	1.08	2.55	2.64	3.05	3.99	1.67	1800	1000	4300	5.11	9.20	2.14
13	1.759	1.776	.724	.942	1.08	1.12	2.77	2.86	3.29	4.27	3.67	1800	1000	3900	4.55	8.19	2.10
14	1.844	1.776	.784	1.01	1.16	1.20	2.84	2.93	3.36	4.34	3.67	1800	910	3900	4.14	8.19	1.91
15	1.954	2.039	.820	1.05	1.18	1.22	3.14	3.22	3.64	4.65	11.80	2000	1000	3600	3.32	6.64	1.84
16	2.048	2.039	.889	1.13	1.27	1.30	3.22	3.31	3.72	4.72	11.80	2000	910	3600	3.02	6.64	1.68
17	2.117	2.204	.887	1.13	1.28	1.32	3.39	3.49	3.95	5.06	10.63	1800	910	3300	3.14	6.21	1.71
18	2.230	2.204	.968	1.23	1.39	1.42	3.49	3.59	4.04	5.14	10.63	1800	820	3300	2.83	6.21	1.54
19	2.256	2.346	.926	1.20	1.37	1.41	3.60	3.72	4.25	5.50	6.30	1500	820	3000	3.32	6.07	1.66
20	2.359	2.346	.999	1.28	1.46	1.51	3.70	3.81	4.33	5.57	6.30	1500	750	3000	3.03	6.07	1.52
21	2.585	2.584	1.08	1.40	1.60	1.65	4.05	4.18	4.78	6.18	4.93	1300	680	2700	2.92	5.57	1.40
22	2.707	2.584	1.17	1.50	1.71	1.76	4.16	4.29	4.88	6.27	4.93	1300	620	2700	2.66	5.57	1.28
23	2.820	2.866	1.13	1.49	1.73	1.80	4.43	4.60	5.34	7.04	1.60	1000	620	2400	3.18	5.14	1.33
24	2.968	2.866	1.23	1.61	1.86	1.93	4.56	4.73	5.47	7.15	1.60	1000	560	2400	2.88	5.14	1.20
25	2.997	3.020	1.28	1.63	1.85	1.90	4.73	4.87	5.50	7.01	10.21	1300	620	2400	2.17	4.55	1.18
26	3.153	3.020	1.40	1.77	1.99	2.04	4.88	5.01	5.63	7.12	10.21	1300	560	2400	1.96	4.55	1.06
27	3.141	3.306	1.31	1.67	1.90	1.95	5.06	5.20	5.90	7.56	10.63	1200	620	2200	2.14	4.14	1.17
28	3.305	3.306	1.42	1.81	2.04	2.10	5.21	5.35	6.03	7.68	10.63	1200	560	2200	1.93	4.14	1.05
29	3.649	3.651	1.57	2.00	2.25	2.32	5.75	5.91	6.66	8.46	11.14	1100	510	2000	1.73	3.73	.951
30	3.801	3.651	1.69	2.13	2.39	2.45	5.89	6.04	6.78	8.57	11.14	1100	470	2000	1.59	3.73	.876
31	3.869	4.079	1.61	2.06	2.33	2.40	6.24	6.41	7.25	9.28	11.80	1000	510	1800	1.69	3.32	.940
32	4.030	4.079	1.73	2.20	2.48	2.54	6.38	6.56	7.39	9.39	11.80	1000	470	1800	1.56	3.32	.866
33	4.302	4.432	1.79	2.30	2.62	2.70	6.85	7.06	8.04	10.4	7.35	820	430	1600	1.67	3.18	.855
34	4.517	4.432	1.94	2.48	2.82	2.90	7.04	7.25	8.22	10.5	7.35	820	390	1600	1.51	3.18	.776
35	4.803	4.853	2.05	2.62	2.95	3.04	7.60	7.81	8.81	11.2	10.76	820	390	1500	1.34	2.82	.732
36	4.999	4.853	2.20	2.78	3.13	3.21	7.78	7.98	8.98	11.4	10.76	820	360	1500	1.24	2.82	.676
37	5.261	5.296	2.14	2.80	3.24	3.36	8.24	8.54	9.88	13.0	2.15	560	330	1300	1.63	2.77	.704
38	5.518	5.296	2.32	3.02	3.47	3.59	8.48	8.77	10.1	13.1	2.15	560	300	1300	1.49	2.77	.640
39	5.530	5.782	2.23	2.91	3.35	3.46	8.83	9.13	10.5	13.7	3.98	560	330	1200	1.48	2.51	.690
40	5.800	5.782	2.41	3.13	3.59	3.71	9.07	9.37	10.7	13.9	3.98	560	300	1200	1.34	2.51	.627
41	6.197	6.433	2.56	3.30	3.77	3.88	9.89	10.2	11.6	15.0	7.05	560	300	1100	1.18	2.20	.600
42	6.532	6.433	2.80	3.58	4.06	4.18	10.20	10.5	11.9	15.3	7.05	560	270	1100	1.06	2.20	.540
43	6.707	6.946	2.72	3.55	4.08	4.22	10.67	11.0	12.7	16.5	4.18	470	270	1000	1.20	2.09	.563
44	7.113	6.946	3.01	3.89	4.44	4.59	11.03	11.4	13.0	16.8	4.18	470	240	1000	1.07	2.09	.501
45	7.465	7.640	3.06	3.98	4.57	4.72	11.81	12.2	14.0	18.2	4.34	430	240	910	1.06	1.89	.500
46	7.797	7.640	3.29	4.25	4.86	5.02	12.11	12.5	14.3	18.5	4.34	430	220	910	.969	1.89	.458
47	8.097	8.391	3.17	4.21	4.92	5.12	12.81	13.3	15.6	20.7	1.14	330	220	820	1.17	1.76	.471
48	8.492	8.391	3.44	4.54	5.28	5.48	13.17	13.7	15.9	20.9	1.14	330	200	820	1.06	1.76	.428
49	9.038	9.296	3.70	4.81	5.52	5.70	14.34	14.8	17.0	22.1	4.83	360	200	750	.861	1.55	.413
50	9.527	9.296	4.05	5.22	5.95	6.14	14.79	15.2	17.4	22.4	4.83	360	180	750	.775	1.55	.372

Table 4. 5th-Degree, 50-Ohm Chebyshev Bandpass Filters Using Standard-Value Capacitors for 6-dB Percentage Bandwidth = Approx. 100%.

DESIGN NO.	F-C (MHZ)	6-DB BW (MHZ)	ATTENUATION LEVELS (DB) 40	20	6	3	3	6	20	40	R.C. (%)	C1,5 (PF)	C2,4 (PF)	C3 (PF)	L1,5 (UH)	L2,4 (UH)	L3 (UH)
			----(LOWER	RANGE)---		(MHZ)		---(UPPER	RANGE)----								
1	.9983	1.246	.354	.474	.554	.575	1.73	1.80	2.10	2.81	4.98	2700	2200	5600	9.41	11.6	4.54
2	1.047	1.246	.386	.512	.595	.617	1.78	1.84	2.14	2.84	4.98	2700	2000	5600	8.56	11.6	4.13
3	1.091	1.362	.385	.516	.605	.629	1.89	1.97	2.31	3.09	4.22	2400	2000	5100	8.86	10.6	4.17
4	1.150	1.362	.423	.562	.656	.680	1.95	2.02	2.35	3.13	4.22	2400	1800	5100	7.97	10.6	3.75
5	1.162	1.507	.407	.542	.632	.655	2.06	2.14	2.49	3.32	7.19	2400	2000	4700	7.81	9.37	3.99
6	1.225	1.507	.446	.591	.685	.709	2.12	2.19	2.54	3.36	7.19	2400	1800	4700	7.03	9.37	3.59
7	1.250	1.613	.429	.578	.681	.709	2.20	2.29	2.70	3.65	3.88	2000	1800	4300	8.10	9.00	3.77
8	1.326	1.613	.476	.637	.746	.774	2.27	2.36	2.76	3.69	3.88	2000	1600	4300	7.20	9.00	3.35
9	1.429	1.819	.508	.675	.784	.812	2.51	2.60	3.03	4.02	7.38	2000	1600	3900	6.20	7.75	3.18
10	1.476	1.819	.537	.711	.824	.853	2.55	2.64	3.06	4.05	7.38	2000	1500	3900	5.82	7.75	2.98
11	1.595	2.039	.577	.759	.874	.902	2.82	2.91	3.35	4.41	11.80	2000	1500	3600	4.98	6.64	2.76
12	1.714	2.039	.654	.852	.974	1.00	2.92	3.01	3.45	4.49	11.80	2000	1300	3600	4.31	6.64	2.40
13	1.771	2.204	.651	.855	.984	1.02	3.09	3.19	3.67	4.82	10.63	1800	1300	3300	4.49	6.21	2.45
14	1.844	2.204	.698	.912	1.05	1.08	3.15	3.25	3.73	4.87	10.63	1800	1200	3300	4.14	6.21	2.26
15	1.996	2.548	.668	.914	1.09	1.14	3.48	3.64	4.35	5.96	1.29	1100	1100	2700	5.78	5.78	2.36
16	2.093	2.548	.728	.989	1.18	1.23	3.57	3.72	4.43	6.02	1.29	1100	1000	2700	5.26	5.78	2.14
17	2.059	2.719	.727	.960	1.11	1.14	3.70	3.83	4.42	5.84	11.80	1500	1200	2700	3.98	4.98	2.21
18	2.151	2.719	.785	1.03	1.19	1.22	3.78	3.90	4.49	5.90	11.80	1500	1100	2700	3.65	4.98	2.03
19	2.284	2.933	.801	1.07	1.25	1.29	4.03	4.18	4.88	6.52	6.30	1200	1000	2400	4.05	4.85	2.02
20	2.395	2.933	.871	1.15	1.34	1.39	4.13	4.27	4.97	6.59	6.30	1200	910	2400	3.68	4.85	1.84
21	2.501	3.200	.879	1.17	1.37	1.42	4.41	4.57	5.33	7.11	6.30	1100	910	2200	3.68	4.45	1.84
22	2.635	3.200	.964	1.28	1.48	1.54	4.52	4.68	5.44	7.20	6.30	1100	820	2200	3.32	4.45	1.66
23	2.763	3.520	.975	1.30	1.52	1.57	4.86	5.04	5.87	7.83	6.30	1000	820	2000	3.32	4.05	1.66
24	2.890	3.520	1.06	1.40	1.62	1.68	4.97	5.14	5.97	7.91	6.30	1000	750	2000	3.03	4.05	1.52
25	2.961	3.821	.988	1.35	1.61	1.69	5.20	5.43	6.49	8.87	1.60	750	750	1800	3.85	3.85	1.60
26	3.110	3.821	1.08	1.46	1.74	1.81	5.33	5.56	6.60	8.96	1.60	750	680	1800	3.49	3.85	1.46
27	3.191	4.079	1.15	1.52	1.75	1.80	5.64	5.83	6.71	8.82	11.80	1000	750	1800	2.49	3.32	1.38
28	3.351	4.079	1.26	1.64	1.88	1.94	5.78	5.96	6.83	8.92	11.80	1000	680	1800	2.26	3.32	1.25
29	3.567	4.586	1.19	1.63	1.95	2.04	6.25	6.53	7.81	10.7	1.49	620	620	1500	3.21	3.21	1.33
30	3.753	4.586	1.31	1.77	2.11	2.20	6.41	6.69	7.95	10.8	1.49	620	560	1500	2.90	3.21	1.20
31	3.809	4.853	1.38	1.81	2.09	2.16	6.72	6.94	8.01	10.5	10.76	820	620	1500	2.13	2.82	1.16
32	4.008	4.853	1.50	1.97	2.26	2.33	6.89	7.11	8.16	10.7	10.76	820	560	1500	1.92	2.82	1.05
33	4.216	5.494	1.48	1.97	2.28	2.37	7.51	7.78	9.04	12.0	8.32	680	560	1300	2.10	2.55	1.10
34	4.417	5.494	1.61	2.12	2.45	2.54	7.69	7.95	9.20	12.2	8.32	680	510	1300	1.91	2.55	.999
35	4.798	6.189	1.73	2.28	2.62	2.70	8.53	8.80	10.1	13.3	13.18	680	510	1200	1.62	2.16	.917
36	4.998	6.189	1.86	2.43	2.78	2.87	8.71	8.97	10.3	13.4	13.18	680	470	1200	1.49	2.16	.845
37	5.202	6.730	1.87	2.46	2.83	2.92	9.26	9.56	11.0	14.5	12.80	620	470	1100	1.51	1.99	.851
38	5.439	6.730	2.03	2.65	3.03	3.12	9.47	9.76	11.2	14.6	12.80	620	430	1100	1.38	1.99	.778
39	5.681	7.375	2.04	2.68	3.09	3.18	10.13	10.5	12.0	15.9	12.34	560	430	1000	1.40	1.83	.785
40	5.965	7.375	2.22	2.90	3.33	3.43	10.38	10.7	12.3	16.0	12.34	560	390	1000	1.27	1.83	.712
41	6.256	8.108	2.24	2.95	3.40	3.51	11.15	11.5	13.2	17.4	12.39	510	390	910	1.27	1.66	.711
42	6.511	8.108	2.41	3.15	3.62	3.73	11.37	11.7	13.4	17.6	12.39	510	360	910	1.17	1.66	.657
43	6.922	8.718	2.49	3.30	3.82	3.95	12.12	12.5	14.5	19.2	8.44	430	330	820	1.23	1.60	.645
44	7.260	8.718	2.71	3.56	4.11	4.25	12.41	12.8	14.8	19.4	8.44	430	300	820	1.12	1.60	.586
45	7.565	9.503	2.72	3.61	4.18	4.33	13.22	13.7	15.9	21.0	8.03	390	300	750	1.13	1.48	.590
46	7.974	9.503	2.99	3.93	4.53	4.68	13.58	14.0	16.2	21.3	8.03	390	270	750	1.02	1.48	.531
47	8.005	10.553	2.79	3.71	4.31	4.46	14.36	14.9	17.3	23.0	8.93	360	300	680	1.10	1.32	.581
48	8.438	10.553	3.06	4.04	4.68	4.83	14.73	15.2	17.6	23.2	8.93	360	270	680	.988	1.32	.523
49	8.858	11.600	3.11	4.13	4.79	4.96	15.84	16.4	19.0	25.2	9.22	330	270	620	.978	1.20	.521
50	9.396	11.600	3.45	4.54	5.24	5.42	16.30	16.8	19.4	25.6	9.22	330	240	620	.869	1.20	.463

Table 5. 5th-Degree, 50-Ohm Chebyshev Bandpass Filters Using Standard-Value Capacitors for 6-dB Percentage Bandwidth = Approx. 125%.

DESIGN NO.	F-C (MHZ)	6-DB BW (MHZ)	40	20	6	3	3	6	20	40	R.C. (%)	C1,5 (PF)	C2,4 (PF)	C3 (PF)	L1,5 (UH)	L2,4 (UH)	L3 (UH)
			---------- ATTENUATION LEVELS (DB) ----------														
			----(LOWER RANGE)---(MHZ)---(UPPER RANGE)----														
1	.9491	1.507	.282	.386	.458	.478	1.89	1.97	2.34	3.20	7.19	2400	3000	4700	11.72	9.37	5.98
2	1.000	1.507	.310	.422	.499	.519	1.93	2.01	2.37	3.23	7.19	2400	2700	4700	10.55	9.37	5.39
3	1.047	1.648	.313	.428	.508	.529	2.07	2.16	2.56	3.50	7.27	2200	2700	4300	10.51	8.56	5.38
4	1.110	1.648	.349	.473	.558	.581	2.12	2.21	2.61	3.54	7.27	2200	2400	4300	9.34	8.56	4.78
5	1.167	1.819	.352	.481	.570	.593	2.29	2.39	2.83	3.87	7.38	2000	2400	3900	9.31	7.75	4.77
6	1.219	1.819	.381	.517	.611	.636	2.34	2.43	2.87	3.90	7.38	2000	2200	3900	8.53	7.75	4.37
7	1.258	1.955	.378	.517	.615	.641	2.47	2.57	3.06	4.19	6.30	1800	2200	3600	8.90	7.28	4.45
8	1.319	1.955	.412	.561	.664	.691	2.52	2.62	3.10	4.22	6.30	1800	2000	3600	8.09	7.28	4.05
9	1.428	2.204	.442	.598	.702	.728	2.80	2.91	3.41	4.61	10.63	1800	2000	3300	6.90	6.21	3.76
10	1.505	2.204	.487	.653	.764	.792	2.86	2.97	3.47	4.66	10.63	1800	1800	3300	6.21	6.21	3.39
11	1.561	2.399	.482	.653	.769	.799	3.05	3.17	3.73	5.06	9.33	1600	1800	3000	6.50	5.77	3.46
12	1.656	2.399	.536	.722	.845	.877	3.13	3.24	3.80	5.11	9.33	1600	1600	3000	5.77	5.77	3.08
13	1.784	2.719	.561	.755	.883	.915	3.48	3.60	4.21	5.67	11.80	1500	1600	2700	5.31	4.98	2.95
14	1.842	2.719	.595	.797	.930	.963	3.52	3.65	4.26	5.71	11.80	1500	1500	2700	4.98	4.98	2.76
15	1.927	3.020	.588	.797	.938	.974	3.81	3.96	4.66	6.31	10.21	1300	1500	2400	5.25	4.55	2.84
16	2.069	3.020	.670	.899	1.05	1.09	3.93	4.07	4.76	6.40	10.21	1300	1300	2400	4.55	4.55	2.46
17	2.093	3.200	.637	.871	1.03	1.08	4.06	4.23	5.03	6.87	6.30	1100	1300	2200	5.26	4.45	2.63
18	2.178	3.200	.686	.932	1.10	1.15	4.13	4.30	5.09	6.92	6.30	1100	1200	2200	4.85	4.45	2.43
19	2.284	3.520	.691	.945	1.12	1.17	4.46	4.64	5.52	7.55	6.30	1000	1200	2000	4.85	4.05	2.43
20	2.386	3.520	.748	1.02	1.20	1.25	4.54	4.72	5.59	7.61	6.30	1000	1100	2000	4.45	4.05	2.22
21	2.524	3.923	.760	1.04	1.24	1.29	4.95	5.16	6.13	8.38	6.76	910	1100	1800	4.37	3.61	2.21
22	2.647	3.923	.830	1.13	1.33	1.39	5.05	5.26	6.21	8.45	6.76	910	1000	1800	3.97	3.61	2.01
23	2.722	4.301	.773	1.08	1.32	1.39	5.35	5.62	6.85	9.59	1.92	680	1000	1600	5.03	3.42	2.14
24	2.854	4.301	.843	1.17	1.42	1.49	5.45	5.72	6.94	9.66	1.92	680	910	1600	4.57	3.42	1.94
25	2.957	4.432	.922	1.25	1.48	1.54	5.68	5.91	6.98	9.49	7.35	820	910	1600	3.53	3.18	1.81
26	3.115	4.432	1.01	1.37	1.61	1.67	5.81	6.04	7.10	9.58	7.35	820	820	1600	3.18	3.18	1.63
27	3.144	4.853	.974	1.32	1.54	1.60	6.17	6.40	7.51	10.1	10.76	820	910	1500	3.13	2.82	1.71
28	3.312	4.853	1.07	1.44	1.68	1.74	6.30	6.53	7.63	10.2	10.76	820	820	1500	2.82	2.82	1.54
29	3.643	5.494	1.14	1.54	1.82	1.89	7.03	7.31	8.62	11.7	8.32	680	750	1300	2.81	2.55	1.47
30	3.826	5.494	1.24	1.67	1.96	2.04	7.18	7.46	8.75	11.8	8.32	680	680	1300	2.55	2.55	1.33
31	3.962	5.926	1.24	1.68	1.98	2.06	7.61	7.91	9.33	12.7	7.72	620	680	1200	2.60	2.37	1.34
32	4.150	5.926	1.35	1.82	2.14	2.22	7.76	8.06	9.47	12.8	7.72	620	620	1200	2.37	2.37	1.23
33	4.325	6.730	1.34	1.81	2.11	2.19	8.54	8.84	10.3	13.9	12.80	620	680	1100	2.18	1.99	1.23
34	4.529	6.730	1.46	1.96	2.28	2.36	8.70	9.01	10.5	14.0	12.80	620	620	1100	1.99	1.99	1.12
35	4.731	7.375	1.46	1.97	2.31	2.40	9.34	9.69	11.3	15.3	12.34	560	620	1000	2.02	1.83	1.13
36	4.978	7.375	1.61	2.15	2.51	2.60	9.54	9.88	11.5	15.4	12.34	560	560	1000	1.83	1.83	1.02
37	5.253	7.813	1.65	2.24	2.64	2.74	10.06	10.5	12.3	16.7	7.70	470	510	910	1.95	1.80	1.01
38	5.472	7.813	1.78	2.40	2.82	2.93	10.24	10.6	12.5	16.8	7.70	470	470	910	1.80	1.80	.930
39	5.800	8.718	1.82	2.46	2.90	3.01	11.18	11.6	13.7	18.5	8.44	430	470	820	1.75	1.60	.918
40	6.064	8.718	1.97	2.65	3.11	3.23	11.40	11.8	13.9	18.7	8.44	430	430	820	1.60	1.60	.840
41	6.319	9.503	1.97	2.67	3.15	3.28	12.18	12.7	14.9	20.2	8.03	390	430	750	1.63	1.48	.846
42	6.635	9.503	2.15	2.90	3.41	3.54	12.44	12.9	15.2	20.4	8.03	390	390	750	1.48	1.48	.767
43	6.686	10.553	2.02	2.74	3.24	3.37	13.27	13.8	16.3	22.2	8.93	360	430	680	1.57	1.32	.833
44	7.021	10.553	2.20	2.98	3.51	3.64	13.54	14.1	16.5	22.4	8.93	360	390	680	1.43	1.32	.756
45	7.672	11.600	2.40	3.25	3.82	3.96	14.85	15.4	18.1	24.5	9.22	330	360	620	1.30	1.20	.694
46	8.013	11.600	2.60	3.49	4.09	4.24	15.13	15.7	18.4	24.7	9.22	330	330	620	1.20	1.20	.636
47	8.151	12.462	2.46	3.38	4.03	4.21	15.80	16.5	19.7	27.0	4.98	270	330	560	1.41	1.16	.681
48	8.549	12.462	2.68	3.66	4.35	4.53	16.13	16.8	20.0	27.3	4.98	270	300	560	1.28	1.16	.619
49	8.911	13.622	2.67	3.68	4.41	4.60	17.25	18.0	21.6	29.7	4.22	240	300	510	1.33	1.06	.625
50	9.393	13.622	2.94	4.02	4.79	5.00	17.65	18.4	21.9	30.0	4.22	240	270	510	1.20	1.06	.563

Table 6. 5th-Degree, 50-Ohm Chebyshev Bandpass Filters Using Standard-Value Capacitors for 6-dB Percentage Bandwidth = Approx. 150%.

2. The center frequency and 6 dB bandwidth of a trial 50 ohm bandpass filter is calculated by multiplying the desired F-c and 6 dB BW values by the impedance scaling factor, R.
3. From the appropriate 50 ohm bandwidth table, a design is selected having the F-c and 6 dB BW closest to the trial filter values. The tabulated capacitor values will be used directly in the new filter, and the frequencies and inductance values will be scaled to the new impedance levels.
4. The new frequencies are calculated by dividing all frequencies by R.
5. The new inductance values are calculated by multiplying the tabular values by R^2.

An example shows how to obtain a 60 ohm bandpass design with a center frequency of 2 MHz and a 6 dB BW of 3 MHz. The following step numbers correspond with the numbers of the previous explanation.

1. The impedance scaling factor, $R = Zx/50 = 60/50 = 1.2$.
2. The trial F-c = 2 MHz (1.2) = 2.4 MHz, and the trial 6 dB BW = 3 MHz (1.2) = 3.6 MHz.
3. The appropriate design table in this case is No. 6 because the percentage bandwidth of the filter is 150%. Scanning the F-c and 6 dB BW columns of Table 6, design No. 20 is selected because the values for this design (2.386 and 3.52 MHz) are closest to the trial values of 2.4 and 3.6 MHz. The tabulated capacitor values for design No. 20 are C1,5 = 1000 pF, C2,4 = 1100 pF and C3 = 2000 pF. These values are used directly in the 60 ohm filter design.
4. The frequencies and inductor values for the trial filter are now scaled to a 60 ohm impedance level by dividing all the frequencies listed for the design by 1.2 and by multiplying all the inductor values by the square of the scaling factor:

   F-center = 2.386 MHz/1.2 = 1.988 MHz,
   6 dB BW = 3.52 MHz/1.2 = 2.933 MHz,
   F-40 dB = 0.748 MHz/1.2 = 0.623 MHz,
   F-20 dB = 1.02 MHz/1.2 = 0.850 MHz,

   . . . and so forth. It should be noted that the final F-c and 6 dB BW of the 60 ohm bandpass filter are close enough to the desired values of 2 and 3 MHz so the design may be used.
5. The inductance values for the 60 ohm filter are:

   L1,5 = 4.45 μH (1.2 squared) = 4.45 μH (1.44) = 6.41 μH,
   L2,4 = 4.05 μH (1.44) = 5.83 μH,
   L3 = 2.22 μH (1.44) = 3.197 μH.

These scaled values derived from Table 6 can be confirmed by using the standard scaling procedure with the normalized component values for a 5-element lowpass filter having a reflection coefficient of 6.3% (see Figure 3). To do this, the following component values normalized for a cutoff frequency of 1 rad/sec and 1 ohm terminations are used: G1,5 = 0.8266; G2,4 = 1.3375; and G3 = 1.6532. The calculation is based on a center frequency of 1.9883 MHz and a ripple bandwidth of 2.193 MHz. The bandpass component values calculated by this independent procedure (explained on page 158 of Reference 1) will produce values essentially identical with the values obtained from the scaling of the bandpass filter tables, thus confirming the validity of the bandpass tables.

Summary

Previously published tables of 50 ohm precalculated low and high-pass filter designs using standard-value capacitors (SVC) were of considerable convenience to the EMI/EMC engineer. These tables permitted one unfamiliar with filter design to quickly select a design for any cutoff frequency and impedance level in which only standard-value capacitors were needed, thus simplifying filter design and construction. This design technique has now been extended to the bandpass filter.

Five tables of precalculated 50 ohm, 5-resonator bandpass filter designs are presented which are expected to be adequate to meet most of the EMI/EMC test specifications requiring this filter type. The percentage bandwidth ranged from 50 to 150 percent in increments of 25% while the center frequencies ranged from 1 MHz to 10 MHz in approximate increments of ten percent. Scaling procedures for other frequency decades and impedance levels were explained to make the tables universally applicable for all bandpass filter applications. A procedure was explained as to how the correctness of the filter tables could be verified.

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