Use of Tables for Filter Implementation

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Dec. 26, 2004, rev. March 9, 2013

After performing tedious pole calculations for various electronic filters it becomes apparent that the calculations are all essentially the same. This fact makes it possible to replace the calculations with a table of normalized values that only need to be scaled to the particular frequency of interest.

The first table is of the pole locations normalized to 1 radian per second for several common filters. Then, the factors for each pole location of the group corresponding to the previously determined order and filter type are multiplied by the cut-off frequency of the desired filter.

Example: Find the pole locations for a fifth order Butterworth low-pass filter with a cut-off frequency of 10 kHz. The first step in the solution is to convert the cut-off frequency to radians per second my multiplying by 6.28. Thus, the cut-off frequency is 62,800 radians per second. The next step is to compute the pole locations of the two quadratic poles and one first order pole by multiplying the factors in the table by -62,800 (the poles are in the left half plane). Thus, we have:

[0.80900 +-j0.58780] * -62,800 = **-50,805 +-j36,914**
[0.30900 +-j0.95110] * -62,800 = **-19,405 +-j59,729**
[1.00000 +-j0.00000] * -62,800 = **-62,800**

The natural frequency and Q associated with each of these poles can then be calculated for use in the algorithm for determining components.

Pole locations are generally not as convenient for circuit implementation as are the natural frequency and Q of each second order section. Therefore, the second table shows data that is computed from that in the first table to provide factors in the more convenient form, natural frequency in Hertz and Q.

Example: The previous example is used. Note that the computational effort is considerably reduced and the result is directly ready for implementation.

Fn1 = 1.00000 * 10,000 = 10,000 Hz, Q1 = 0.6180
Fn2 = 1.00000 * 10,000 = 10,000 Hz, Q2 = 1.6182
Fn3 = 1.00000 * 10,000 = 10,000 Hz

Note that in all cases the filter cutoff frequency is the -3 dB frequency.

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Spreadsheet to convert low-pass filter poles to F, Q

lpf_tlb.xls written by Kenneth A. Kuhn version 1.0

data taken from Electronic Filter Design Handbook, Arthur B. Williams, McGraw-Hill Book Company, 1981, pages 12-1 to 12-45.

Pole locations for: Filter cut-off frequency is normalized to 1 radian/second

Order	1 dB Chebyshev		0.5 dB Chebyshev		0.25 dB Chebyshev		0.1 dB Chebyshev		Butterworth		Bessel	
	-sigma	+- jw	-sigma	+- jw	-sigma	+- jw	-sigma	+- jw	-sigma	+- jw	-sigma	+- jw
2	0.45080	0.73510	0.51290	0.72250	0.56210	0.71540	0.61040	0.71060	0.70710	0.70710	1.10300	0.63680
3	0.22570	0.88220	0.26830	0.87530	0.30620	0.87120	0.34900	0.86840	0.50000	0.86600	1.05090	1.00250
	0.45130		0.53660		0.61240		0.69790		1.00000		1.32700	
4	0.31990	0.38680	0.38720	0.38500	0.45010	0.38400	0.21770	0.92540	0.92390	0.38270	1.35960	0.40710
	0.13250	0.93390	0.16050	0.92970	0.18650	0.92720	0.52570	0.38330	0.38270	0.92390	0.98770	1.24760
5	0.22650	0.59180	0.27670	0.59020	0.32470	0.58920	0.38420	0.58840	0.80900	0.58780	1.38510	0.72010
	0.08652	0.95750	0.10570	0.95500	0.12400	0.95330	0.14680	0.95210	0.30900	0.95110	0.96060	1.47560
	0.28000		0.34200		0.40130		0.47490		1.00000		1.50690	
6	0.22680	0.26010	0.27840	0.25960	0.32840	0.25930	0.39160	0.25900	0.96590	0.25880	1.57350	0.32130
	0.16600	0.71060	0.20370	0.70910	0.24040	0.70830	0.28670	0.70770	0.70710	0.70710	1.38360	0.97270
	0.06076	0.97070	0.07459	0.96870	0.08799	0.96750	0.10490	0.96670	0.25880	0.96590	0.93180	1.66400
7	0.18190	0.43540	0.22410	0.43490	0.26520	0.43440	0.31780	0.43410	0.90100	0.43390	1.61300	0.58960
	0.12590	0.78460	0.15500	0.78360	0.18350	0.78280	0.22000	0.78230	0.62350	0.78180	1.37970	1.19230
	0.04494	0.97850	0.05534	0.97710	0.06550	0.97610	0.07850	0.97550	0.22250	0.97490	0.91040	1.83750
	0.20190		0.24870		0.29440		0.35280		1.00000		1.68530	
8	0.17370	0.19560	0.21440	0.19550	0.25430	0.19530	0.30580	0.19520	0.98080	0.19510	1.76270	0.27370
	0.14730	0.55710	0.18170	0.55650	0.21560	0.55610	0.25920	0.55580	0.83150	0.55560	0.89550	2.00440
	0.09840	0.83370	0.12140	0.83280	0.14410	0.83230	0.17320	0.83190	0.55560	0.83150	1.37800	1.39260
	0.03456	0.98360	0.04264	0.98240	0.05058	0.98170	0.06082	0.98120	0.19510	0.98080	1.64190	0.82530
9	0.14820	0.34270	0.18310	0.34250	0.21760	0.34230	0.26220	0.34210	0.93970	0.34200	1.80810	0.51260
	0.12080	0.64420	0.14930	0.64360	0.17740	0.64330	0.21370	0.64300	0.76600	0.64280	1.65320	1.03190
	0.07884	0.86790	0.09743	0.86710	0.11580	0.86670	0.13950	0.86630	0.50000	0.86600	1.36830	1.56850
	0.02739	0.98690	0.03383	0.98610	0.04021	0.98560	0.04845	0.98520	0.17370	0.98480	0.87880	2.15090
	0.15770		0.19490		0.23150		0.27900		1.00000		1.85750	

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Computed data from pole table Multiply desired cut-off frequency by fc factor

Order	1 dB Chebyshev fc factor	1 dB Chebyshev Q	0.5 dB Chebyshev fc factor	0.5 dB Chebyshev Q	0.25 dB Chebyshev fc factor	0.25 dB Chebyshev Q	0.1 dB Chebyshev fc factor	0.1 dB Chebyshev Q	Butterworth fc factor	Butterworth Q	Bessel fc factor	Bessel Q
2	0.8623	0.9564	0.8860	0.8638	0.9098	0.8093	0.9368	0.7673	1.0000	0.7071	1.2736	0.5773
3	0.9106	2.0173	0.9155	1.7061	0.9234	1.5079	0.9359	1.3408	1.0000	1.0000	1.4524	0.6910
	0.4513		0.5366		0.6124		0.6979		1.0000		1.3270	
4	0.5019	0.7845	0.5460	0.7051	0.5916	0.6572	0.9507	2.1834	1.0000	0.5412	1.4192	0.5219
	0.9433	3.5594	0.9435	2.9391	0.9458	2.5356	0.6506	0.6188	1.0000	1.3065	1.5912	0.8055
5	0.6337	1.3988	0.6518	1.1779	0.6727	1.0359	0.7027	0.9145	1.0000	0.6180	1.5611	0.5635
	0.9614	5.5559	0.9608	4.5451	0.9613	3.8763	0.9634	3.2812	1.0000	1.6182	1.7607	0.9165
	0.2800		0.3420		0.4013		0.4749		1.0000		1.5069	
6	0.3451	0.7608	0.3807	0.6836	0.4184	0.6371	0.4695	0.5995	1.0000	0.5176	1.6060	0.5103
	0.7297	2.1980	0.7378	1.8109	0.7480	1.5557	0.7636	1.3316	1.0000	0.7071	1.6913	0.6112
	0.9726	8.0036	0.9716	6.5127	0.9715	5.5205	0.9724	4.6348	1.0000	1.9319	1.9071	1.0234
7	0.4719	1.2971	0.4892	1.0916	0.5090	0.9596	0.5380	0.8464	1.0000	0.5550	1.7174	0.5324
	0.7946	3.1558	0.7988	2.5767	0.8040	2.1908	0.8126	1.8469	1.0000	0.8019	1.8235	0.6608
	0.9795	10.8982	0.9787	8.8423	0.9783	7.4679	0.9787	6.2335	1.0000	2.2471	2.0507	1.1262
	0.2019		0.2487		0.2944		0.3528		1.0000		1.6853	
8	0.2616	0.7530	0.2902	0.6767	0.3206	0.6304	0.3628	0.5932	1.0000	0.5098	1.7838	0.5060
	0.5762	1.9560	0.5854	1.6109	0.5964	1.3832	0.6133	1.1830	1.0000	0.6013	2.1953	1.2258
	0.8395	4.2657	0.8416	3.4662	0.8447	2.9309	0.8497	2.4531	1.0000	0.9000	1.9591	0.7109
	0.9842	14.2391	0.9833	11.5305	0.9830	9.7173	0.9831	8.0819	1.0000	2.5628	1.8376	0.5596
9	0.3734	1.2597	0.3884	1.0605	0.4056	0.9320	0.4310	0.8219	1.0000	0.5321	1.8794	0.5197
	0.6554	2.7129	0.6607	2.2126	0.6673	1.8808	0.6776	1.5854	1.0000	0.6527	1.9488	0.5894
	0.8715	5.5268	0.8726	4.4779	0.8744	3.7755	0.8775	3.1450	1.0000	1.0000	2.0815	0.7606
	0.9873	18.0226	0.9867	14.5829	0.9864	12.2659	0.9864	10.1795	1.0000	2.8785	2.3235	1.3220
	0.1577		0.1949		0.2315		0.2790		1.0000		1.8575	