APPENDICES

Appendix A

A.1: Coefficients of denominator polynomial, in the form $s^n + a_1 s^{n-1} + a_2 s^{n-2} + ... + a_{n-2} s^2 + a_{n-1} s + 1$, for Butterworth filter function of order n , with pass-band from 0 to 1 rad/sec[+].

n	a_1	a_2	a_3	a_4	a_5	a_6
2	1.4142					
3	2.0000	2.0000				
4	2.6131	3.4142	2.6131			
5	3.2361	5.2361	5.2361	3.2361		
6	3.8637	7.4641	9.1416	7.4641	3.8637	
7	4.4940	10.0978	14.5918	14.5918	10.0978	4.4940

A.2: Coefficients of denominator polynomial, in the form $s^n + a_1 s^{n-1} + a_2 s^{n-2} + ... + a_{n-2} s^2 + a_{n-1} s + a_n$, for Chebyshev filter function of order n, with pass-band from 0 to 1 rad/sec[+].

Pass-band ripple A_p	n	a_1	a_2	a_3	a_4	a_5	a_6
0.5 dB ε=0.3493	1	2.863					
	2	1.425	1.516				
	3	1.253	1.535	0.716			
	4	1.197	1.717	1.025	0.379		
	5	1.1725	1.9374	1.3096	0.7525	0.1789	
	6	1.1592	2.1718	1.5898	1.1719	0.4324	0.0948
1.0 dB ε=0.5089	1	1.965					
	2	1.098	1.103				
	3	0.988	1.238	0.491			
	4	0.953	1.454	0.743	0.276		
	5	0.9368	1.6888	0.9744	0.5805	0.1228	
	6	0.9282	1.9308	1.2021	0.9393	0.3071	0.0689
2.0 dB ε=0.7648	1	1.308					
	2	0.804	0.637				
	3	0.738	1.022	0.327			
	4	0.716	1.256	0.517	0.206		
	5	0.7065	1.4995	0.6935	0.4593	0.0817	
	6	0.7012	1.7459	0.8670	0.7715	0.2103	0.0514

A.3: Coefficients of denominator polynomial, in the form $s^n + a_1 s^{n-1} + a_2 s^{n-2} + ... + a_{n-2} s^2 + a_{n-1} s + a_n$, for Bessel-Thomson filter function of order n[+].

n	a_1	a_2	a_3	a_4	a_5	a_6
1	1					
2	3	3				
3	6	15	15			
4	10	45	105	105		
5	15	105	420	945	945	
6	21	210	1260	4725	10395	10395

[+] R. Schaumann et al, "Design of Analog Filters- Passive, Active RC, and Switched Capacitor", Prentice-Hall Inc., © 1990

Appendix B

B.1: Element interconnections and values for *all-pole* low-pass single-resistance-terminated lossless ladder. Figures B.1(a)-(b) are the structures for voltage source driven with even and odd order filters respectively. Figures B.1(c)-(d) are for current source driven with even and odd order filters respectively.[!] The element values for several orders are given in **TABLE B.1**.

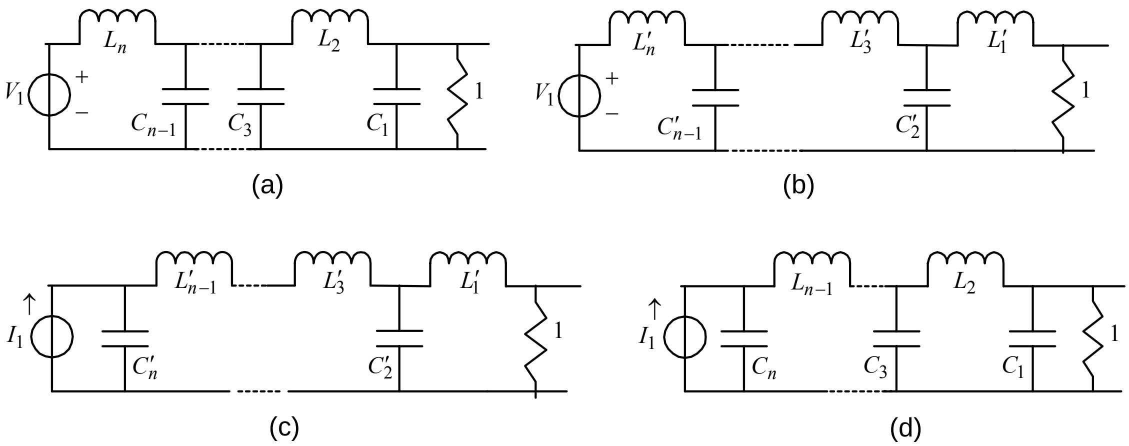


Figure B.1:

TABLE B.1

n	C_1	L_2	C_3	L_4	C_5	L_6	C_7
2	.7071	1.4142	**Butterworth**	(1 rad/s bandwidth)			
3	.5000	1.3333	1.5000				
4	.3827	1.0824	1.5772	1.5307			
5	.3090	.8944	1.3820	1.6944	1.5451		
2	.7014	.9403	**0.5 dB ripple**	**Chebyshev**			
3	.7981	1.3001	1.3465	(1 rad/s bandwidth)			
4	.8352	1.3916	1.7279	1.3138			
5	.8529	1.4291	1.8142	1.6426	1.5388		
2	.9110	.9957	**1 dB ripple**	**Chebyshev**			
3	1.0118	1.3332	1.5088	(1 rad/s bandwidth)			
4	1.0495	1.4126	1.9093	1.2817			
5	1.0674	1.4441	1.9938	1.5908	1.6652		
2	.3333	1.0000		**Bessel-Thomson**			
3	.1667	.4800	.8333	(1 s delay at DC)			
4	.1000	.2899	.4627	.7101			
5	.0667	.1948	.3103	.4215	.6231		
6	.0476	.1400	.2246	.3005	.3821	.5595	
7	.0357	.1055	.1704	.2288	.2827	.3487	.5111
n	L_1’	C_2’	L_3’	C_4’	L_5’	C_6’	L_7’

[!] L.P.Huelsman, “Active and Passive Analog Filter Design – An Introduction”, McGraw-Hill, Inc., ©1993.

B.2: Element interconnections and values for *all-pole* low-pass double-resistance-terminated lossless ladder. Figures B.2(a)-(b) are the structures for even and odd order filters respectively. Figures B.2(c)-(d) are alternate structures for even and odd order filters respectively.[1] The element values for several orders are given in **TABLE B.2**.

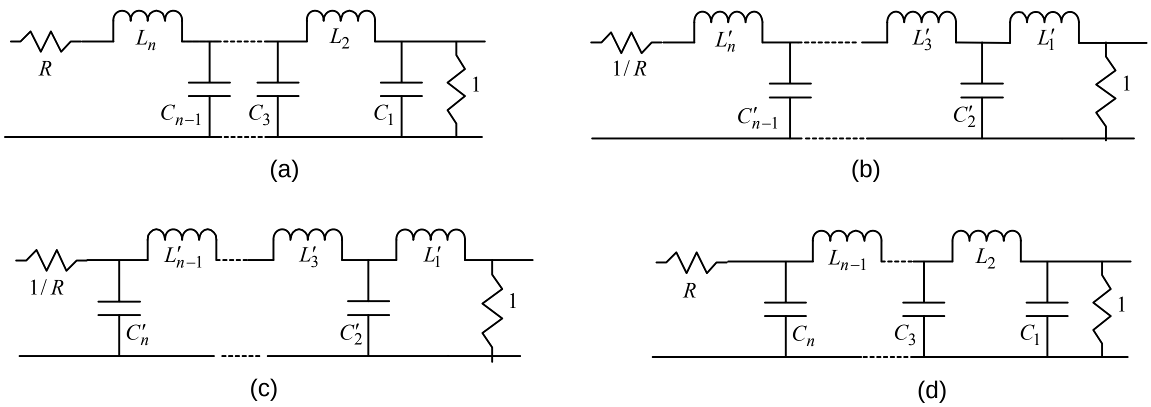


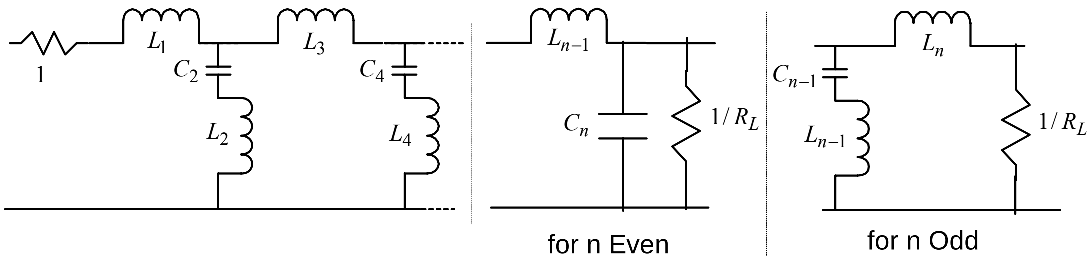
Figure B.2:

TABLE B.2

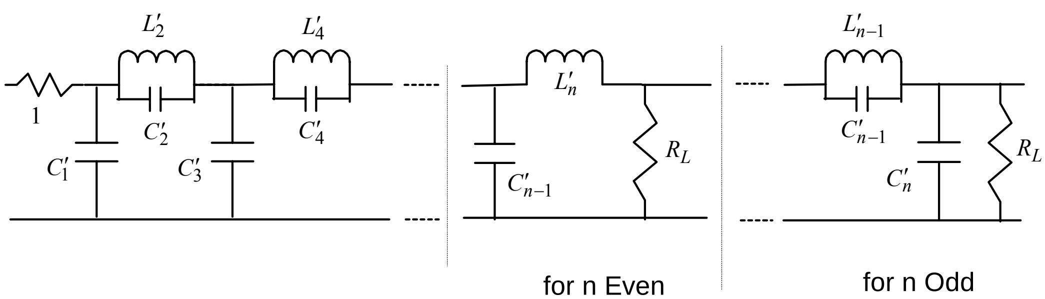
n	C_1	L_2	C_3	L_4	C_5	L_6	C_7
2	1.4142	1.4142	**Butterworth**	(1 rad/s bandwidth)			
3	1.0000	2.0000	1.0000				
4	.7654	1.8478	1.8478	.7654			
5	.6180	1.6180	2.0000	1.6180	.6180		
3	1.5963	1.0967	1.5963	**0.5 dB ripple**	**Chebyshev**	(1 rad/s bandwidth)	
5	1.7058	1.2296	2.5408	1.2296	1.7058		
7	1.7373	1.2582	2.6383	1.3443	2.6383	1.2582	1.7373
3	2.0236	.9941	2.0236	**1 dB ripple**	**Chebyshev**	(1 rad/s bandwidth)	
5	2.1349	1.0911	3.0009	1.0911	2.1349		
7	2.1666	1.1115	3.0936	1.1735	3.0936	1.1115	2.1666
2	1.5774	.4226		**Bessel-Thomson**			
3	1.2550	.5528	.1922	(1 s delay at DC)			
4	1.0598	.5116	.3181	.1104			
5	.9303	.4577	.3312	.2090	.0718		
6	.8377	.4116	.3158	.2364	.1480	.0505	
7	.7677	.3744	.2944	.2378	.1778	.1104	.0375
n	L_1’	C_2’	L_3’	C_4’	L_5’	C_6’	L_7’

[1] L.P.Huelsman, “Active and Passive Analog Filter Design – An Introduction”, McGraw-Hill, Inc., ©1993.

B.3: Element values for *elliptic* low-pass double-resistance-terminated lossless ladder. Figures in B.3(a) show the structures for even and odd order filters respectively. Figures in B.3(b) are alternate structures for even and odd order filters respectively.[!]



(a)



(b)

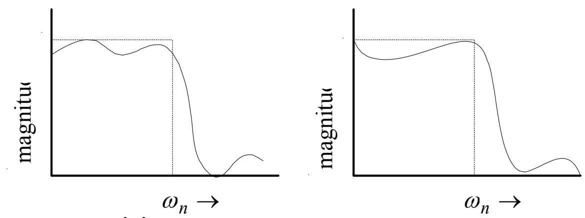
Figure B.3:

TABLE B.3A provide element values for odd orders of several values and also for several even order values for the case when the response at infinite frequency is forced to zero by adopting a modified expression for the transfer function. In this transfer function the denominator is of degree *n* while the numerator degree is forced to be *n-2*. The expression has the form:

$$H_N(s) = \frac{H_c \prod_{i=2}^{n/2} (s^2 + \Omega_i^2)}{a_0 + a_1 s + \ldots + a_{n-1} s + a_n s^n} \qquad \ldots \text{(B.3.1)}$$

In this case the load and source resistances are equal with a value of 1Ω each. **TABLE B.3B** provide alternate set of element values for several even orders, where the modified elliptic transfer function has the same form as in Eq. B.3.1 above, but the values of the Ω_i are slightly different. As a result the transition band slope becomes different. The nature of difference for order n=4 may be appreciated by considering figures B.4(a)-(b). The difference lies in the magnitude of the transfer function at DC (zero frequency). This is similar to the case of even and odd order Chebyshev approximation functions. The source and load resistances for this alternate case, are unequal with R_s= 1 Ω. In each of these tables only two values have been used for A_p, i.e., .1 dB and 1.0 dB.

[!] L.P.Huelsman, "Active and Passive Analog Filter Design – An Introduction", McGraw-Hill, Inc., ©1993.



(a) (b)

Figure B.4:

TABLE B.3A

n	ω_s	A_a	L_1	C_2	L_2	L_3	C_4	L_4	L_5	(see Fig. B.3(a))
3	1.05	1.748	.35550	.15374	5.39596	.35550				
	1.10	3.374	.44626	.26993	2.70353	.44626				
	1.20	6.691	.57336	.44980	1.30805	.57336				
	1.50	14.848	.77031	.74561	.47797	.77031				
	2.00	24.010	.89544	.93759	.20697	.89544				0.1-dB passband ripple
4	1.05	3.284	.00442	.17221	4.93764	1.01224	.84445			
	1.10	6.478	.17279	.32758	2.30986	1.04894	.89415			
	1.20	12.085	.37139	.56638	1.09294	1.11938	.92440			
	1.50	23.736	.62815	.94009	.40730	1.24711	.93518			
	2.00	36.023	.77554	1.17646	.17957	1.33473	.93382			
5	1.05	13.841	.70813	.76630	.73572	1.12761	.20138	4.38116	.04985	
	1.10	20.050	.81296	.92418	.49338	1.22445	.37193	2.13500	.29125	
	1.20	28.303	.91441	1.06516	.31628	1.38201	.60131	1.09329	.52974	
	1.50	43.415	1.02789	1.21517	.15134	1.63179	.93525	.44083	.81549	
	2.00	58.901	1.08758	1.29322	.07317	1.79387	1.14330	.20038	.97720	

n	ω_s	A_a	C_1'	L_2'	C_2'	C_3'	L_4'	C_4'	C_5'	(see Fig.B.3(b))
3	1.05	8.134	1.05507	.25223	3.28904	1.05507				
	1.10	11.480	1.22525	.37471	1.94752	1.22525				
	1.20	16.209	1.42450	.52544	1.11977	1.42450				
	1.50	25.176	1.69200	.73340	.48592	1.69200				
	2.00	34.454	1.85199	.85903	.22590	1.85199				
4	1.05	11.322	.63708	.35277	2.41039	1.11522	1.39953			
	1.10	15.942	.80935	.54042	1.40015	1.18107	1.45001			1.0-dB passband ripple
	1.20	22.293	1.00329	.77733	.79634	1.26621	1.49217			
	1.50	34.179	1.25675	1.11431	.34362	1.38981	1.53225			
	2.00	46.481	1.40677	1.32367	.15960	1.46762	1.55071			
5	1.05	24.135	1.56191	.67560	.83449	1.55460	.26584	3.31881	.88528	
	1.10	30.471	1.69691	.77511	.58827	1.79892	.39922	1.98907	1.12109	
	1.20	38.757	1.82812	.87005	.38720	2.09095	.56347	1.16672	1.38094	
	1.50	53.875	1.97687	.97694	.18824	2.49161	.79362	.51950	1.71889	
	2.00	69.360	2.05594	1.03392	.09152	2.73567	.93561	.24486	1.91939	

TABLE B.3B

n	ω_s	A_a	L_1	C_2	L_2	L_3	C_4	L_4	L_5	C_6	*(see Fig. B.3(a))*
4	1.05	4.485	.15780	.18091	4.73822	1.20743	.82637				
	1.10	8.308	.33411	.33438	2.28333	1.26881	.84827				
	1.20	14.387	.53773	*.55478*	*1.12558*	1.36980	.85261				
	1.50	26.320	.79962	.88310	.43628	1.53672	.84068				0.1-dB passband ripple
	2.00	38.697	.95051	1.08631	.19517	1.64684	.83004				$R_L=0.73781\ \Omega$
6	1.05	20.307	.57153	*.65752*	1.01346	.92972	.32584	2.72744	1.03524	.88809	
	1.10	27.889	.70783	.81703	.67992	1.10484	.51890	1.54640	1.19779	.88523	
	1.20	37.827	.84244	.98082	.43111	1.32791	.75659	.88144	1.37708	.87992	
	1.50	55.966	.99836	1.17887	.20248	1.64500	1.08849	.38623	1.61158	.87198	
	2.00	74.548	1.08280	1.28970	.09690	1.84134	1.29301	.18123	1.75160	.86710	
4	1.05	13.243	.95111	.26779	3.20104	1.90749	.80699				
	1.10	18.140	1.16239	.39958	1.91077	2.05228	.80907				
	1.20	24.700	1.40135	*.56068*	1.11374	2.23453	.80633				1.0-dB passband ripple
	1.50	36.771	1.71483	.78307	.49201	2.49368	.79924				$R_L=0.37598\ \Omega$
	2.00	49.156	1.90048	.91820	.23091	2.65459	.79441				
6	1.05	30.730	1.40432	.58067	1.14761	1.37588	.31837	2.79144	1.79883	.82259	
	1.10	38.342	1.56906	.69149	.80335	1.66832	.45609	1.75937	1.99786	.82076	
	1.20	48.285	1.73631	.80659	.52424	2.01190	.62218	1.07185	2.22816	.81822	
	1.50	66.425	1.93461	.94611	.25229	2.47740	.85305	.49283	2.53990	.81461	
	2.00	85.008	2.04359	1.02402	.12205	2.75884	.99547	.23540	2.72966	.81243	
			C_1'	L_2'	C_2'	C_3'	L_4'	C_4'	C_5'	L_6'	*(see Fig. B.3(b))*