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Design Data for *m*-Derived Type Filters

PART VII

By the Engineering Department, Aerovox Corporation

CUT-OFF FREQUENCIES along the response curve for the *m*-derived band-suppression filter section, unlike those of the band-pass section, lie farthest from the mid-frequency. The frequencies of maximum attenuation lie closest to the mid-frequency which is the geometric mean between the two former. Starting at the low-frequency end of the band-suppression response curve, the operating frequencies are arranged in this order: lower cut-off frequency (f_0), lower frequency of maximum attenuation ($f_1'\infty$), mid-frequency f_m), upper frequency of maximum attenuation ($f_1\infty$), and upper cut-off frequency (f_1). The ideal band-suppression response curve appeared on page 5 of Part I of this series (*Aerovox Research Worker*, September-October 1942).

BAND WIDTH

The band-suppression filter section removes a band of frequencies from a complex waveform, the width of this band being governed by placement of the cut-off and infinite attenuation frequencies. In the compilation of band-suppression filter data, the editors have selected twelve practical band widths, ratios of ($f_1\infty$-$f_1\infty$ to f_m) from 0.05 to 0.9. Chart 5, accompanying this article, lists fo, $f_1'\infty$, $f_1\infty$, and f_1 values corresponding to these bandwidths, for twenty-three fm values from 100 cycles per second to 10 megacycles.

INFINITE ATTENUATION POINTS

The two frequencies of maximum attenuation have been spaced on the mid-frequency side of each cut-off frequency at a distance from the latter equal to 5 percent of the corresponding cut-off frequency. This placement permits infinite attenuation at frequencies close enough to the cut-off frequencies to lower the transmission characteristic sharply without destroying transmission at other frequencies.

VARIATION OF *m*

In the band-suppression section, *m* is a complex term which varies with the band width. For both series- and shunt-derived circuits:

$$m = \sqrt{\frac{\left(1-\frac{f_0^2}{f_{1\infty}^2}\right)\left(1-\frac{f_{1\infty}^2}{f_1^2}\right)}{1-\frac{f_0}{f_1}}}$$

For bandwidths from 0.05 to 0.9, the numerical value of *m* varies from 0.355 to 0.377, as shown in Table 2.

FREQUENCY CHART

All frequency values may be taken directly from Chart 5. Listings are in cycles per second except in the last four columns which are given in kilocycles and megacycles.

Use of the frequency chart is straightforward. For example: a band-suppression section designed for 1000-cycle operation with a bandwidth of 0.3 will have its lower and upper cut-off frequencies (fo and f_1) at 819 and 1220 c.p.s. respectively. Its lower and upper infinite-attenuation freqquencies ($f_1'\infty$ and $f_1\infty$) are 862 and 1162 c.p.s.

The frequency chart may be used to determine operating frequencies corresponding to other mid-frequencies than those listed. The method is simple: Choose a desired mid-frequency and bandwidth. From Chart 5, select the 100-cycle values opposite this bandwidth figure, and multiply the former by the ratio of the desired mid-frequency to 100 cycles. Example: What are the operating frequencies for a band-suppression section having a mid-frequency of 7250 cycles and bandwidth of 0.8? Ans.—7250 is not listed in the Chart as a mid-frequency. The multiplier therefore will be 7250/100 or 72.5, the ratio of the two mid-frequencies. The frequencies listed opposite 0.8 bandwidth in the 100-cycle column accordingly must be multiplied by 72.5 to obtain the 7250-cycle values. When the desired mid-frequency is higher than 100 cycles, the ratio will be greater than 1; when less than 100 cycles, the ratio will be a decimal.

TABLE 2
Variation of *m* with Band Width, Band-Suppression Filters

BAND WIDTH	*m*
0.05	0.355
0.1	0.366
0.15	0.373
0.2	0.376
0.25	0.377
0.3	0.377
0.4	0.375
0.5	0.371
0.6	0.367
0.7	0.363
0.8	0.359
0.9	0.355

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CHART 5—Frequency Data, Band-Suppression Filters, Series- and Shunt-Derived

Band Width		f_m = 100	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
0.05	f_0	92.6	926	1390	1852	2316	2780	3244	3705	4170	4632	5094	5560
	$f'_{1\infty}$	97.5	975	1463	1950	2438	2926	3414	3900	4389	4876	5362	5852
	$f_{1\infty}$	102.5	1025	1538	2050	2563	3076	3589	4100	4614	5126	5637	6152
	f_1	107.6	1076	1615	2152	2691	3230	3768	4305	4844	5382	5919	6459
0.1	f_0	90	904	1356	1807	2259	2711	3162	3614	4065	4518	4969	5421
	$f'_{1\infty}$	95	951	1427	1902	2378	2853	3328	3804	4279	4756	5230	5706
	$f_{1\infty}$	105	1051	1577	2102	2628	3153	3678	4204	4729	5256	5780	6306
	f_1	110	1103	1656	2207	2759	3311	3862	4414	4965	5519	6069	6621
0.15	f_0	89	882	1322	1763	2203	2645	3086	3527	3967	4409	4849	5290
	$f'_{1\infty}$	93	928	1392	1856	2319	2784	3248	3712	4176	4641	5104	5568
	$f_{1\infty}$	108	1078	1617	2156	2694	3234	3773	4312	4851	5391	5929	6468
	f_1	113	1132	1698	2264	2829	3396	3961	4527	5093	5660	6225	6791
0.2	f_0	86	865	1292	1729	2148	2594	3026	3458	3890	4324	4755	5187
	$f'_{1\infty}$	90	910	1360	1820	2261	2730	3185	3640	4095	4551	5005	5460
	$f_{1\infty}$	110	1110	1660	2220	2761	3330	3885	4440	4995	5551	6105	6660
	f_1	115	1165	1743	2331	2899	3496	4079	4662	5245	5828	6410	6993
0.25	f_0	84	839	1258	1678	2097	2517	2936	3355	3774	4195	4613	5033
	$f'_{1\infty}$	88	883	1324	1766	2207	2649	3090	3532	3973	4416	4856	5298
	$f_{1\infty}$	113	1133	1699	2266	2832	3399	3965	4532	5098	5666	6231	6798
	f_1	119	1190	1784	2379	2974	3569	4163	4759	5353	5949	6542	7138
0.3	f_0	82	819	1227	1638	2048	2457	998	3276	3685	4096	4504	4913
	$f'_{1\infty}$	86	862	1292	1724	2156	2586	1050	3448	3879	4311	4741	5172
	$f_{1\infty}$	116	1162	1742	2324	2906	3486	4067	4648	5229	5811	6391	6972
	f_1	122	1220	1829	2440	3051	3660	4270	4880	5490	6101	6710	7321
0.4	f_0	78	780	1169	1560	1948	2340	2729	3120	3509	3901	4289	4680
	$f'_{1\infty}$	82	821	1230	1642	2050	2463	2873	3284	3694	4106	4515	4926
	$f_{1\infty}$	122	1221	1830	2442	3050	3663	4273	4884	5494	6106	6715	7326
	f_1	128	1282	1921	2564	3202	3846	4487	5128	5769	6411	7051	7692
0.5	f_0	74	742	1112.5	1484	1854.4	2226.9	2596	2986	3338	3711	4080	4452
	$f'_{1\infty}$	78	781	1171	1562	1952	2343	2733	3124	3514	3906	4295	4686
	$f_{1\infty}$	128	1281	1921	2562	3202	3843	4483	5124	5764	6406	7045	7686
	f_1	134.4	1345	2017	2690	3362	4035	4707	5380	6052	6726	7397	8070
0.6	f_0	71	707	1060	1414	1767	2120	2474	2827	3181	3535	3887	4241
	$f'_{1\infty}$	74	744	1116	1488	1860	2232	2604	2976	3348	3721	4092	4464
	$f_{1\infty}$	134	1344	2016	2688	3360	4032	4704	5376	6048	6721	7392	8064
	f_1	141	1411	2117	2822	3528	4233	4939	5645	6350	7057	7762	8467
0.7	f_0	68	685	532	1349	1686	2024	2361	2698	3035	3374	3710	4047
	$f'_{1\infty}$	71	710	1064	1420	1775	2130	2485	2840	3195	3551	3905	4260
	$f_{1\infty}$	141	1410	2114	2820	3525	4230	4935	5640	6345	7051	7755	8460
	f_1	148	1480	2220	2961	3701	4441	5182	5922	6662	7403	8143	8883
0.8	f_0	65	643	965	1286	1607	1930	2251	2573	2894	3217	3537	3859
	$f'_{1\infty}$	68	677	1016	1354	1692	2031	2369	2708	3046	3386	3723	4062
	$f_{1\infty}$	148	1477	2216	2954	3692	4431	5169	5908	6646	7386	8123	8862
	f_1	155	1551	2327	3102	3876	4652	5427	6203	6978	7755	8529	9305
0.9	f_0	62	618	922	1235	1544	1853	2161	2470	2826	3089	3396	3705
	$f'_{1\infty}$	65	650	970	1300	1625	1950	2275	2600	2975	3251	3575	3900
	$f_{1\infty}$	155	1550	2320	3100	3875	4650	5425	6200	6975	7751	8525	9300
	f_1	163	1627	2436	3255	4069	4882	5696	6510	7324	8138	8951	9765

CHART 5—Frequency Data, Band-Suppression Filters, Series- and Shunt-Derived

Band Width		f_m = 6500	7000	7500	8000	8500	9000	9500	10 kc.	100 kc.	1 Mc.	10 Mc.
0.05	f_0	6019	6482	6945	7408	7871	8334	8797	9.26	92.6	0.926	9.262
	$f_{1\infty}'$	6337	6475	7312	7800	8287	8775	9260	9.75	97.5	0.975	9.750
	$f_{1\infty}$	6662	7175	7687	8200	8456	9225	9737	10.25	102.5	1.025	10.250
	f_1	6994	7532	8070	8608	9146	9684	10220	10.76	107.6	1.076	10.762
0.1	f_0	5869	6321	6772	7224	7675	8127	8578	9.03	90.3	0.903	9.034
	$f_{1\infty}'$	6181	6657	7132	7608	8083	8559	9034	9.51	95.1	0.951	9.510
	$f_{1\infty}$	6831	7357	7882	8408	8933	9459	9984	10.51	105.1	1.051	10.510
	f_1	7169	7721	8272	8824	9375	9927	10478	11.03	110.3	1.103	11.035
0.15	f_0	5707	6146	6585	7024	7463	7902	8341	8.78	87.8	0.878	8.787
	$f_{1\infty}'$	6012	6475	6937	7400	7862	8325	8787	9.25	92.5	0.925	9.250
	$f_{1\infty}$	6987	7525	8062	8600	9137	9675	10212	10.75	107.5	1.075	10.750
	f_1	7332	7896	8460	9024	9588	10152	10716	11.28	112.8	1.128	11.287
0.2	f_0	5583	6013	6442	6872	7201	7731	8160	8.59	85.9	0.859	8.597
	$f_{1\infty}'$	5882	6335	6787	7240	7692	8145	8597	9.05	90.5	0.905	9.050
	$f_{1\infty}$	7182	7735	8287	8840	9392	9945	10497	11.05	110.5	1.105	11.050
	f_1	7540	8120	8700	9280	9860	10440	11020	11.60	116.0	1.160	11.602
0.25	f_0	5447	5866	6285	6704	7123	7542	7961	8.38	83.8	0.838	8.388
	$f_{1\infty}'$	5739	6181	6625	7064	7505	7947	10388	8.83	88.3	0.883	8.830
	$f_{1\infty}$	7364	7931	8497	9064	9630	10197	10763	11.33	113.3	1.133	11.330
	f_1	7728	8323	8917	9512	10106	10701	11295	11.89	118.9	1.189	11.896
0.3	f_0	5310	5719	6127	6536	6944	7353	7761	8.17	81.7	0.817	8.170
	$f_{1\infty}'$	5590	6020	6450	6880	7310	7740	8170	8.60	86.0	0.860	8.600
	$f_{1\infty}$	7540	8120	8700	9280	9860	10440	11020	11.60	116.0	1.160	11.600
	f_1	7917	8526	9135	9744	10353	10962	11571	12.18	121.8	1.218	12.180
0.4	f_0	5057	5446	5835	6224	6613	7002	7791	7.78	77.8	0.778	7.780
	$f_{1\infty}'$	5323	5733	6142	6552	6961	7371	7780	8.19	81.9	0.819	8.190
	$f_{1\infty}$	7923	8533	9142	9752	10361	10971	11580	12.19	121.9	1.219	12.190
	f_1	8313	8953	9592	10332	10871	11511	12240	12.79	127.9	1.279	12.799
0.5	f_0	4816	5187	5557	5928	6298	6669	7039	7.41	74.1	0.741	7.410
	$f_{1\infty}'$	5070	5460	5850	6240	6630	7020	7410	7.80	78.0	0.780	7.800
	$f_{1\infty}$	8320	8960	9600	10240	10880	11520	12160	12.80	128.0	1.280	12.800
	f_1	8736	9408	10080	10752	11424	12096	12768	13.44	134.4	1.344	13.440
0.6	f_0	4589	4942	5295	5648	6001	6354	6707	7.06	70.6	0.706	7.068
	$f_{1\infty}'$	4836	5208	5580	5952	6324	6696	7068	7.44	74.4	0.744	7.440
	$f_{1\infty}$	8736	9408	10080	10752	11424	12096	12768	13.44	134.4	1.344	13.440
	f_1	9171	9877	10580	11288	11993	12699	13404	14.11	141.1	1.411	14.112
0.7	f_0	4374	4711	5047	5384	5720	6057	6393	6.73	67.3	0.673	6.735
	$f_{1\infty}'$	4608	4963	5317	5672	6026	6381	6735	7.09	70.9	0.709	7.090
	$f_{1\infty}$	9158	9863	10567	11272	11976	12681	12385	14.09	140.9	1.409	14.090
	f_1	9613	10353	11092	11832	12581	13311	14050	14.79	147.9	1.479	14.794
0.8	f_0	4173	4494	4815	5136	5457	5778	6099	6.42	64.2	0.642	6.426
	$f_{1\infty}'$	4392	4732	5070	5408	5746	6084	6422	6.76	67.6	0.676	6.765
	$f_{1\infty}$	9594	10332	11070	11808	12546	13284	14020	14.76	147.6	1.476	14.765
	f_1	10075	10850	11625	12400	13175	13950	14725	15.50	155.0	1.550	15.503
0.9	f_0	3991	4298	4605	4912	5219	5526	5833	6.14	61.4	0.614	6.146
	$f_{1\infty}'$	4205	4529	4852	5176	5499	5823	6146	6.47	64.7	0.647	6.470
	$f_{1\infty}$	10055	10829	11602	12376	13149	13923	14696	15.47	154.7	1.547	15.470
	f_1	10556	11368	12180	12992	13804	14816	15428	16.24	162.4	1.624	16.243

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