# Design and Implementation of a Passive High-Pass Filter

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EEL3112C section 01

### Equipment used:

- Function Generator
  - o Sweep mode was used, but a non-sweeping FG can be used
  - o Any audio DAC can substitute an FG after calibration for differing impedances
- Oscilloscope
  - A 4-channel sampling oscilloscope with FFT was used, but only one channel was necessary for measurements
  - An audio ADC and averaging time-series plotting software can substitute an oscilloscope after calibration for differing impedances
- Multimeter
  - o For measurement of the capacitor's and resistor's values
- Note: Ideally, a bode plotter would be used to measure the frequency response of the filter, but one was not readily available.

#### Theoretical Results:

The primary equation for the selection of a resistor and capacitor network is the following:

$$2\pi f_{c} = \frac{1}{RC}$$

For  $f_c = 4000$ , the following equation prevails:

$$8000\pi = \frac{1}{RC}$$

Thus, the resistor and capacitor values can be chosen freely or subject to other external constraints based on the above derived formula.

#### Components:

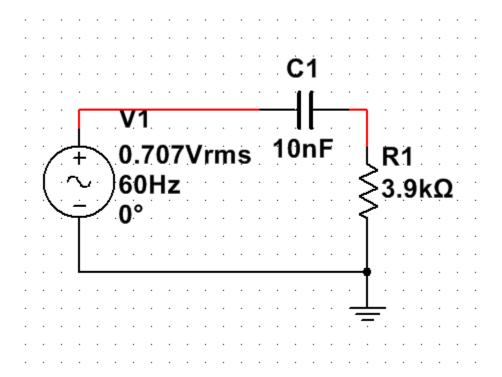
For this design, resistors and capacitors were used due to the greater market variety of both resistors and capacitors comparted to alternate filter designs such as resistor-inductor passive filters. For the full selection matrix computation, see Appendix A

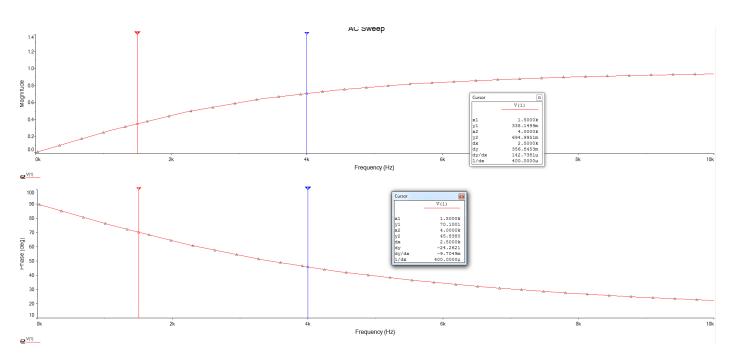
Values	R (Ω)	C (F)	3db attenuation freg (Hz)
Selected	3900	1.00x10 <sup>-8</sup>	4080.89598
Actual	3853.4	9.10x10 <sup>-9</sup>	4538.73

The component pair above was selected due to having a small footprint and availability of parts.

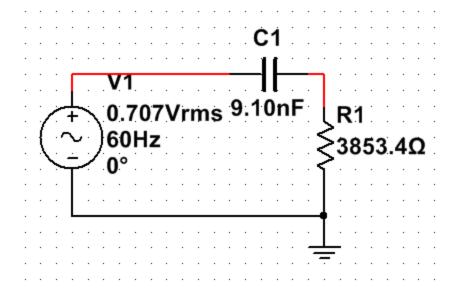
#### Simulation Schematic and Results:

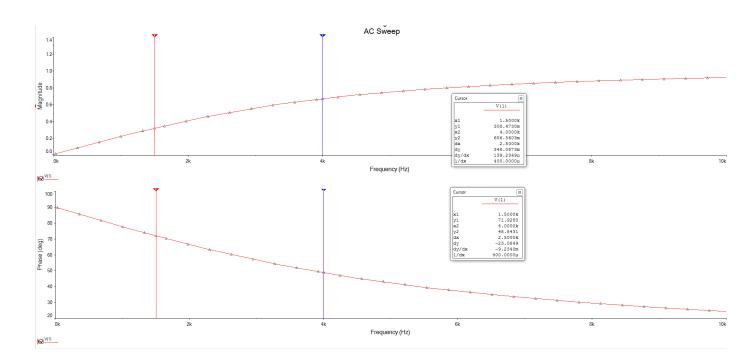
The theoretical circuit schematic and simulated sinusoidal sweep response from  $1~\rm{Hz}$  to  $10~\rm{kHz}$  is shown in the figures below. The simulation was performed in MultiSim.





Likewise, the experimental circuit (with measured resistor and capacitor values) is displayed below with the simulated sinusoidal sweep response



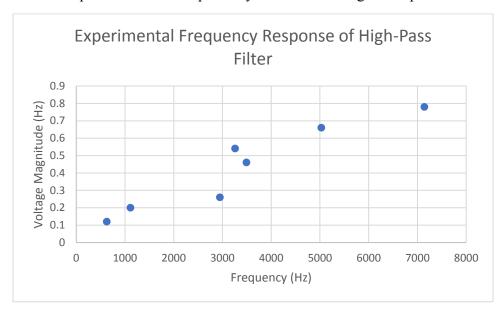


## **Experimental Results:**

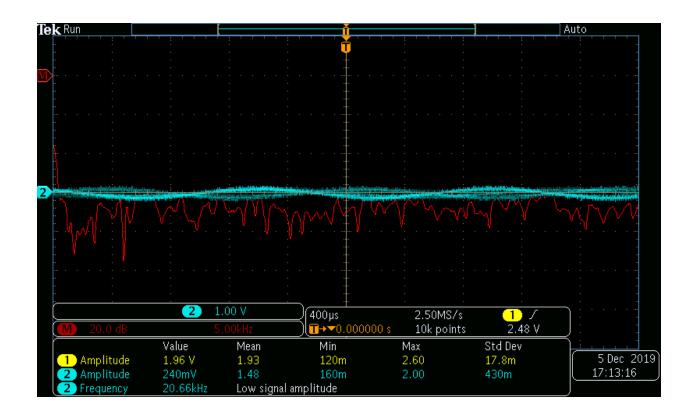
The following values were produced using the function generator set to sweep mode from 1 Hz to 10kHz with a sweep period of 15 seconds. The long sweep period was set to ensure that the oscilloscope could capture images of the waveforms at the passband and stopband frequencies. The values are tabulated and plotted below.

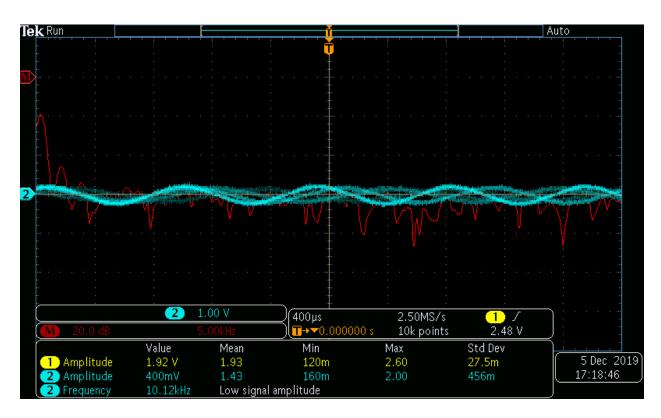
Frequency	
(Hz)	$V_{mag}(V)$
625*	0.12
1111*	0.2
2948	0.26
3259	0.54
3492	0.46
5028	0.66
7143	0.78

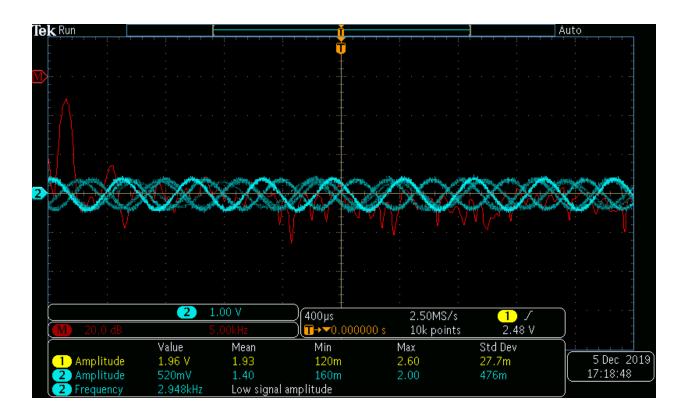
\*these frequencies were computed by manual counting of the period due to measurement noise

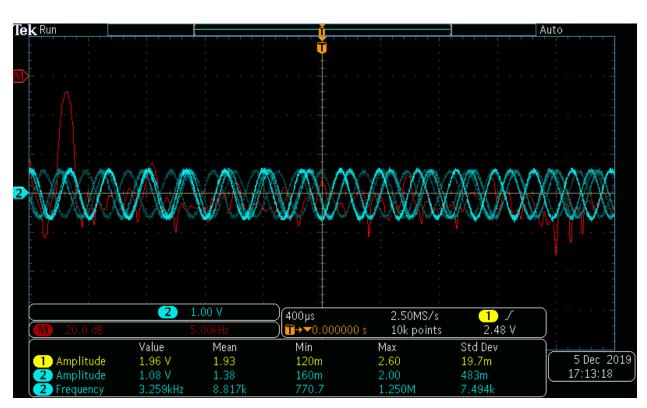


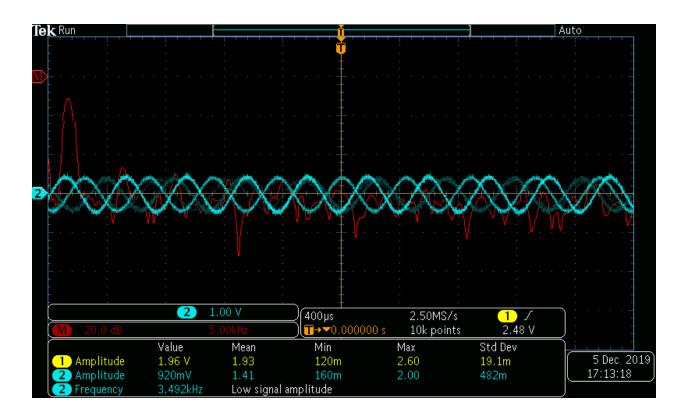
The oscilloscope screenshots below are in ascending order of frequency. The red graph displayed is the oscilloscope's built-in Fast Fourier Transform (FFT) function. However, the FFT graph is for reference purposes only, as the smallest resolution available is 5kHz per division, which is higher than the cutoff frequency.

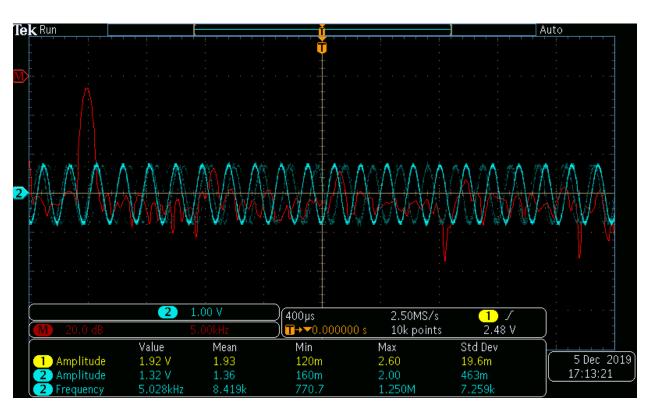


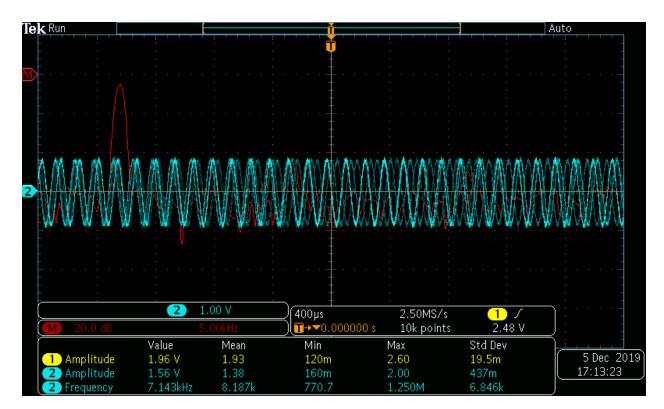












Results: The filter performs close to expectations, with a shift in the cutoff frequency due to component tolerance deviations.

Appendix A: Full Resistor-Capacitor Matching Matrix

The green highlights correspond to the frequency values within 15% of the nominal cutoff frequency of 4 kHz. The purple highlighted value represents the selected pair in the components section. Computations were performed in bulk by Excel and compatible spreadsheet programs.

The green highlights correspond to the frequency values within 15% of the nominal cutoff frequency of 4 kHz. The purple highlighted value represents the selected pair in the components section. Computations were performed in bulk by Excel and compatible spreadsheet programs.																									
combined R↓ C	l table					Src of edge	values	Nilsson, R	iedel: Electric	Circuits (10e	), p. 761			0.0000002	0.0000004										
$\rightarrow$	1E-11							2.2E-09	4.7E-09				1.00E-07	2	7	0.000001				0.000022	0.000047				F
10	15915494 31		33862753 8		72343156	33862753. 8		7234315.6		1591549.4 3	723431.56		159154.94 3	72343.156		15915.494 3	7234.3156		1591.5494 3	723.43156	338.62753 8		72.343156	33.862753 8	
15	10610329 54	48228770 6	22575169 2	10610329 5	48228770. 6	22575169. 2	10610329. 5	4822877.0 6	) 2257516.9 S 2	1061032.9 5	482287.70 6	225751.69 2	106103.29 5	48228.770 6	22575.169 2	10610.329 5	4822.8770 6	2257.5169 2	1061.0329 5	482.28770 6	225.75169 2	106.10329 5	48.228770 6	22.575169 2	
22	72343156	32883252		72343156		15392160.	7234315.6		1539216.0	723431.56		153921.60	72343.156		15392.160	7234.3156		1539.2160	723.43156	328.83252	153.92160	72.343156	32.883252	15.392160	
22	48228770	21922168	_						3 1026144.0											219.22168				10.261440	
33	6 33862753	5 3 15392160	6 72048412.	6 33862753.	5 15392160.	6 7204841.2	6 3386275.3	5 1539216.0	6 720484.12	6 338627.53	5 153921.60	6 72048.412	6 33862.753	5 3 15392.160	6 7204.8412	6 3386.2753	5 1539.2160	6 720.48412	6 338.62753	5 153.92160	6 72.048412	6 33.862753	5 15.392160	6 7.2048412	
47	8 23405138	8 10638699	4 49798167.	8 23405138.	8 10638699	4 4979816 7	8 2340513.8	1063869.9	3 4 9 497981.67	8 234051 38	8 106386 99	4 49798 167	23405 138	8 10638 699	4 4979 8167	8 2340 5138	8 1063 8699	4 497 98167	8 234.05138	8 106.38699	4 49 798167	8 23.405138	8 10 638699	4 4 9798167	
68	7	4	4	7	4	4	7	4	4	7	4	4	. 7	4	4	7	4	4	7	4	4	. 7	4	4	
100		72343156	8		7234315.6	8		723431.56	8		72343.156	8		7234.3156	8		723.43156	8		72.343156	8		7.2343156	3.3862753 8	
120	13262911 9	60285963.	28218961. 5	13262911. 9	6028596.3	2821896.1 5	1326291.1 9	602859.63	3 282189.61 5	132629.11 9	60285.963 3	28218.961 5	13262.911 9	6028.5963	2821.8961 5	1326.2911 9	602.85963 3	282.18961 5	132.62911 9	60.285963	28.218961 5	13.262911 9	6.0285963 3	2.8218961 5	
150	10610329	48228770.	22575169.	10610329.	4822877.0	2257516.9	1061032.9	482287.70	225751.69	106103.29	48228.770	22575.169	10610.329	4822.8770	2257.5169	1061.0329	482.28770	225.75169	106.10329	48.228770	22.575169	10.610329	4.8228770	2.2575169	
130	88419412.	40190642.			4019064.2		884194.12				40190.642			4019.0642			401.90642			40.190642			4.0190642		
180	8		18812641 15392160.		<del>-</del>	1881264.1 1539216.0	_		2 188126.41 2 153921.60			18812.641 15392.160			1881.2641 1539.2160			188.12641 153.92160			18.812641 15.392160			1.8812641 1.5392160	
220	72343156 58946275.			7234315.6 5894627.5			723431.56 589462.75		7 8 1 125417.60	72343.156 58946.275			7234.3156 5894.6275			723.43156 589.46275			72.343156 58.946275	7 26.793761		7.2343156 5.8946275		8 1.2541760	
270	2	2 5 . 21922168.	7	2	5	7	2	5	7 3 102614.40	2	5	7	2	. 5	7	2	5	7	2	5	7	4.8228770	5	7 1.0261440	
330	6	5 5	6	6	5	6	6	5	5 6	6	5	6	6	5	6	6	5	6	6	5	6	6	5	6	
390	40808959. 8		8682757.4	8		868275.74		2	86827.574	8		8682.7574	. 8		868.27574	8		86.827574	8		8.6827574		2	0.8682757 4	
470	33862753. 8	. 15392160. 8 8	7204841.2 4	3386275.3	1539216.0 8	720484.12 4	338627.53 8	153921.60 8	) 72048.412 3 4	33862.753 8	15392.160 8	7204.8412 4	3386.2753 8	3 1539.2160 8 8	720.48412 4	338.62753 8	153.92160 8	72.048412 4	33.862753 8	15.392160 8	7.2048412 4	3.3862753 8	1.5392160 8	0.7204841 2	
560	28420525. 6	. 12918420.	6046920.3	2842052.5 6	1291842.0 7	604692.03	284205.25 6	129184.20 7	60469.203	28420.525 6	12918.420 7	6046.9203 3	2842.0525	1291.8420 7	604.69203	284.20525 6	129.18420 7	60.469203	28.420525 6	12.918420 7	6.0469203	2.8420525	1.2918420 7	0.6046920	
690	23405138.	10638699.	4979816.7	2340513.8	1063869.9	497981.67	234051.38	106386.99	49798.167	23405.138	10638.699	4979.8167	2340.5138	1063.8699	497.98167	234.05138	106.38699	49.798167	23.405138	10.638699	4.9798167	2.3405138	1.0638699	0.4979816	
000	15915494.			1591549.4	4	338627.53	159154.94			15915.494	4		1591.5494			159.15494			15.915494	4	3.3862753	1.5915494	0.7234315	0.3386275	
1000		7234315.6 6028596.3			723431.56 602859.63	8 282189.61	_	72343.156 60285.963	8 3 28218.961		7234.3156 6028.5963			723.43156 602.85963		3 132.62911	72.343156 60.285963			7.2343156 6.0285963	8 2.8218961	3 1.3262911	6 0.6028596	4 0.2821896	
1200	9 10610329.	3 . 4822877.0	5 2257516.9	9 1061032.9	3 482287.70	5 225751.69	9 106103.29	48228.770	5 22575.169	9 10610.329	3 4822.8770	5 2257.5169	9 1061.0329	3 482.28770	5 225.75169	9 106.10329	3 48.228770	5 22.575169	9 10.610329	3 4.8228770	5 2.2575169	9 1.0610329	3 0.4822877	2 0.2257516	
1500	5	6 4019064.2	2	5 884104 12	6 401906.42	2	5 88419.412	6	5 2	5	6 4019.0642	2	5 884 10412	6 401.90642	2	5	6 40.190642	2	5 8 8410412	6 4.0190642	2	5	0.4019064	0 1881264	
1800	8	3 2	1881264.1	8	2	188126.41	8	2	18812.641	8	2	1881.2641	8	3 2	188.12641	8	2	18.812641	8	2	1.8812641	_	2	1	
2200	7234315.6	7	_	723431.56	7		72343.156	7		7234.3156	7		723.43156	7		72.343156	7		7.2343156	7	8	0.7234315 6	3	1	
2700	5894627.5 2	5 2679376.1 2 5	1254176.0 7	589462.75 2	267937.61 5	125417.60 7	58946.275 2	26793.761 5	12541.760 7	5894.6275 2	2679.3761 5	1254.1760 7	589.46275 2	5 267.93761 2 5	125.41760 7	58.946275 2	26.793761 5	12.541760 7	5.8946275 2	2.6793761 5	1.2541760 7	0.5894627 5	0.2679376 1	0.1254176 1	
3300	4822877.0 6	2192216.8	1026144.0	482287.70 6	219221.68	102614.40	48228.770 6	21922.168	3 10261.440 6	4822.8770 6	2192.2168 5	1026.1440 6	482.28770	219.22168	102.61440 6	48.228770 6	21.922168	10.261440 6	4.8228770 6	2.1922168	1.0261440 6	0.4822877	0.2192216	0.1026144 1	
2000	4080895.9	1854952.7			185495.27	06007.574	40808.959	18549.527		4080.8959				185.49527			18.549527	0.6007574	4.0808959	1.8549527	0.8682757			0.0868275	
3900	3386275.3	3 1539216.0	868275.74 720484.12			86827.574 72048.412	33862.753		2 8682.7574 7204.8412			868.27574 720.48412			86.827574 72.048412			8.6827574 7.2048412	3.3862753	1.5392160		0.4080896 0.3386275		0.0720484	
4700	8 2842052.5	8 5 1291842.0	4 604692.03	8 284205.25	8 129184.20	4 60469.203	8 28420.525	8 12918.420	3 4 ) 6046.9203	8 2842.0525	8 1291.8420	4 604.69203	8 284.20525	8 5 129.18420	4 60.469203	8 28.420525	8 12.918420	4 6.0469203	8 2.8420525	8 1.2918420	2 0.6046920	4 0.2842052	1 0.1291842	1	
5600	6 2340513 8	7 8 1063869 9	3 497981 67	6 234051 38	7 106386.99	3 49798.167	6 23405.138	7 10638.699	7 3 9 4979 8167	6 2340.5138	7 1063.8699	3 497.98167	234 05138	7 3 106.38699	3 49.798167	6 23.405138	7 10.638699	3 4.9798167	6 2.3405138	7 1 0638699	3 0 4979816	6 0.2340513	-	0.0604692 0.0497981	
6800	7	4	4	7 159154.94	4	4	7 15915.494	4	4	7	4	4	7	4	4	7	4	4	7	4	7	9 0.1591549	9	7 0.0338627	
10000	1591549.4	723431.56		3	72343.156	8	3	7234.3156	8	-	723.43156	8	-	72.343156	8	_	7.2343156	8	3	6	4	4	6	5	
12000	1326291.1 9	602859.63	282189.61 5	132629.11 9	60285.963	28218.961 5	13262.911 9	6028.5963	3 2821.8961 3 5	1326.2911 9	602.85963 3	282.18961 5	132.62911 9	60.285963 3	28.218961 5	13.262911 9	6.0285963 3	2.8218961 5	1.3262911 9	0.6028596	0.2821896 2	0.1326291 2	0.0602859 6	0.0282189 6	
15000	1061032.9 5	482287.70 6	225751.69 2	106103.29 5	48228.770 6	22575.169 2	10610.329 5	4822.8770 6	) 2257.5169 3 2	1061.0329 5	482.28770 6	225.75169 2	106.10329 5	48.228770 6	22.575169 2	10.610329 5	4.8228770 6	2.2575169 2	1.0610329 5	0.4822877 1		0.1061033	0.0482287 7	0.0225751 7	
18000	884194.12	401906.42	188126.41		40190.642	18812.641	8841.9412 8		2 1881.2641	884.19412 8		188.12641		40.190642	18.812641		4.0190642 2		0.8841941	0.4019064	0.1881264 1	0.0884194	0.0401906	0.0188126	
	700404 50	328832.52	153921.60	1	32883.252	15392.160		3288.3252	1539.2160			153.92160	1	32.883252	15.392160		3.2883252		0.7234315	0.3288325	0.1539216	0.0723431	0.0328832	0.0153921	
				72343.156 58946.275			7234.3156 5894.6275		8 1254.1760	723.43156 589.46275	267.93761		72.343156 58.946275			7.2343156 5.8946275		8 1.2541760	6 0.5894627	0.2679376	1 0.1254176	6 0.0589462	5 0.0267937	0.0125417	
27000		5 219221.68	7 102614.40	2 48228.770	5 21922.168	7 10261.440	2 4822.8770	5 2192.2168	5 7 3 1026.1440	2 482.28770	5 219.22168	7 102.61440	48.228770	5 21.922168	7 10.261440	2 4.8228770	5 2.1922168	7 1.0261440	5 0.4822877	1 0.2192216	1 0.1026144	8 0.0482287	6 0.0219221	6 0.0102614	
	6	5 5	6	6	5	6	6	5	6	6	5	6	6	5 5	6	6	5	6	1	8	1	7	7	4	
39000	8	3 2	86827.574	8	2	8682.7574	8	2	868.27574	8	2	86.827574	. 8	2	8.6827574	8	2	4	0.4080896	7	7	6	3	6	
47000	8	8	4	8	8	4	8	8		8	8	4		8	4	8	8	2	4	1	1	5	6	4	
	284205.25 6	129184.20 7	60469.203 3	28420.525 6	12918.420 7	6046.9203	2842.0525 6	1291.8420 7	604.69203 3	284.20525 6	129.18420 7	60.469203 3	28.420525 6	12.918420 7	6.0469203 3	2.8420525 6	1.2918420 7	u.6046920 3		0.1291842 1			0.0129184 2	0.0060469 2	

		106386.99	49798.167	23405.138	10638.699	4979.8167	2340.5138	1063.8699	497.98167	234.05138	106.38699	49.798167	23.405138	10.638699	4.9798167	2.3405138	1.0638699	0.4979816	0.2340513	0.1063869	0.0497981	0.0234051		0.0049798
68000	7	4	. 4	. 7	4	4	7	4	4	7	4	4	7	4	4	7	4	7	9	9	7		0.0106387	2
100000	159154.94	72343.156		15915.494 3	7234.3156		1591.5494	723.43156	338.62753	159.15494	72.343156		15.915494	7.2343156		1.5915494	0.7234315	0.3386275	0.1591549 1	0.0723431	0.0338627	0.0159154 o	0.0072343	0.0033862 8
100000					6028.5963		_						-			1.3262911	0.6028596	0.2821896	0.1326291	0.0602859	0.0282189	0.0132629	2	0
120000	9	3	5	9	3	5	9	3	5	9	3	5	9	3	5	9	3	2	2	6	6	1	0.0060286	0.0028219
		48228.770	22575.169	10610.329	4822.8770	2257.5169	1061.0329	482.28770	225.75169	106.10329	48.228770	22.575169	10.610329	4.8228770		1.0610329	0.4822877			0.0482287	0.0225751	0.0106103	0.0048228	0.0022575
150000		6	5 2	5	6	2	5	6	2	5	6	2	5	6	2	ວ	1		0.1061033		7	3	8	2
180000			18812 641		4019.0642		884.19412					18 8126/1		4.0190642			0.4019064	0.1881264	0.0884194	0.0401906	0.0188126	0.0088419	0.0040190	0.0018812
100000	U				3288.3252												0.3288325	0.1539216	0.0723431	0.0328832	0.0153921	0.0072343	0.0032883	0.0015392
220000	72343.156				7										8	6	3	1	6	5	6	2	3	2
		26793.761	12541.760	5894.6275	2679.3761	1254.1760	589.46275	267.93761	125.41760	58.946275	26.793761	12.541760	5.8946275	2.6793761	1.2541760	0.5894627	0.2679376	0.1254176	0.0589462	0.0267937	0.0125417	0.0058946	0.0026793	0.0012541
270000	2	5	7	2	5	7	2	5	7	2	5	7	4 0000770	5	7	5	1	1	8	6	6	3	8	8
330000	48228.770	21922.168	3 10261.440 5 6	0 4822.8770 6 6	2192.2168	1026.1440	482.28770	219.22168	102.61440	48.228770	21.922168	10.261440	4.8228770	2.1922168	1.0261440	0.4822877	0.2192216	0.1026144	0.0482287	0.0219221	0.0102614	0.0048228 8	0.0021922	0.0010261
		18549.527	,	4080.8959	1854.9527	O	408.08959	185.49527	O	40.808959	18.549527	O	4.0808959	1.8549527	0.8682757	'	0.1854952	0.0868275	0.0408089	0.0185495	0.0086827	O	0.0018549	0.0008682
					2											0.4080896		7	6	3		0.0040809	5	8
		15392.160	7204.8412	3386.2753	1539.2160	720.48412	338.62753	153.92160	72.048412	33.862753	15.392160	7.2048412	3.3862753	1.5392160	0.7204841	0.3386275	0.1539216	0.0720484	0.0338627	0.0153921	0.0072048	0.0033862	0.0015392	0.0007204
470000	8	40040 400	4	. 8	8	4	8	8	4	8	8	4	8	8	2	4	1	1	5	6	4	8	2	8
560000	28420.525	12918.420	0 6046.9203	2842.0525	1291.8420	604.69203	284.20525	129.18420	60.469203	28.420525	12.918420	6.0469203	2.8420525	1.2918420	0.6046920	0.2842052		0.0604692	0.0284205	0.0129184	0.0060469	0.0028420	0.0012918	0.0006046 a
300000	_	10638 699	3 4979 8167	2340 5138	1063.8699	497 98167	234 05138	106 38699	49 798167	23 405138	10 638699	4 9798167	2 3405138	1 0638699	0 4979816	0 2340513		0.0004092	0.0234051	2	0 0049798	0 0023405	0 0010638	0 0004979
680000	7	4	4	. 7	4	4	7	4	4	7	4	4	7	4	7	9	9	7		0.0106387		1	7	8
100000	15915.494												1.5915494	0.7234315	0.3386275	0.1591549	0.0723431	0.0338627	0.0159154	0.0072343	0.0033862	0.0015915	0.0007234	0.0003386
0	_	7234.3156			723.43156		3			3			3	6	4	4	6	5	9	2	8	5	3	3
150000	10610.329	4822.8770	2257.5169	1061.0329	482.28770	225.75169	106.10329	48.228770	22.575169	10.610329	4.8228770	2.2575169	1.0610329	0.4822877		0.1061033		0.0225751	0.0106103	0.0048228 g	0.0022575	0.0010610	0.0004822	0.0002257
220000	3	3288.3252	1539.2160	. J	328.83252	153.92160	3	32.883252	15.392160	3	3.2883252	1.5392160	0.7234315	0.3288325	_	0.1001033		0.0153921	0.0072343	0.0032883	0.0015392	0.0007234	0.0003288	0.0001539
	7234.3156			723.43156			72.343156			7.2343156		8	6	3	1	6	5	6	2	3	2	3	3	2
330000	4822.8770	2192.2168	1026.1440	482.28770	219.22168	102.61440	48.228770	21.922168	10.261440	4.8228770	2.1922168	1.0261440	0.4822877	0.2192216	0.1026144	0.0482287	0.0219221	0.0102614	0.0048228	0.0021922	0.0010261	0.0004822	0.0002192	0.0001026
0	6	5	6	6	5	6	6	5	6	6	5	6	1	8	1	7	7	4	8	2	4	9	2	1
470000	3386.2753	1539.2160	720.48412	338.62753	153.92160	72.048412	33.862753	15.392160	7.2048412	3.3862753	1.5392160	0.7204841	0.3386275	0.1539216	0.0720484	0.0338627	0.0153921	0.0072048	0.0033862	0.0015392	0.0007204	0.0003386	0.0001539	7.2048E-
680000	2340 5138	გ 1063 გ600	, 497 98167	·	გ 106 38699	49 798167	8 23 405138	10 638699	4 4 9798167	გ 2 3405138	8 1 0638699	2 0.4979816	4 0 2340513	0 1063869	0 0497981	0.0234051	0	4 0 0049798	0 0023405	2 0 0010638	0 0 0004979	0.0002340	0 0001063	∪5 4 <u>9</u> 798F-
0	7	4	4	. 201.00100	4	4	7	4	4	7	4	7	9	9	7		0.0106387	2.00 +07.00	1	7	8.000-070	5.0002040	9	05
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