Design and Implementation of a Passive High-Pass Filter

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EEL3112C section 01

Equipment used:

- Function Generator
  - Sweep mode was used, but a non-sweeping FG can be used
  - 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
  - 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:

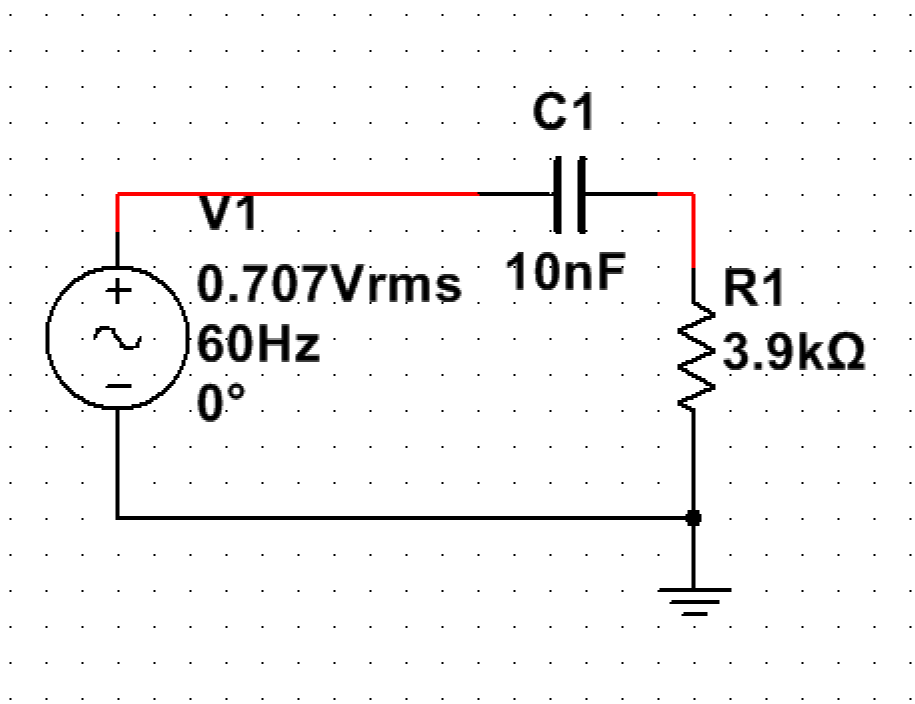
For this design, resistors and capacitors were used due to the greater market variety of both resistors and capacitors comparted to alternate filter designs such as resistor-inductor passive filters. For the full selection matrix computation, see Appendix A

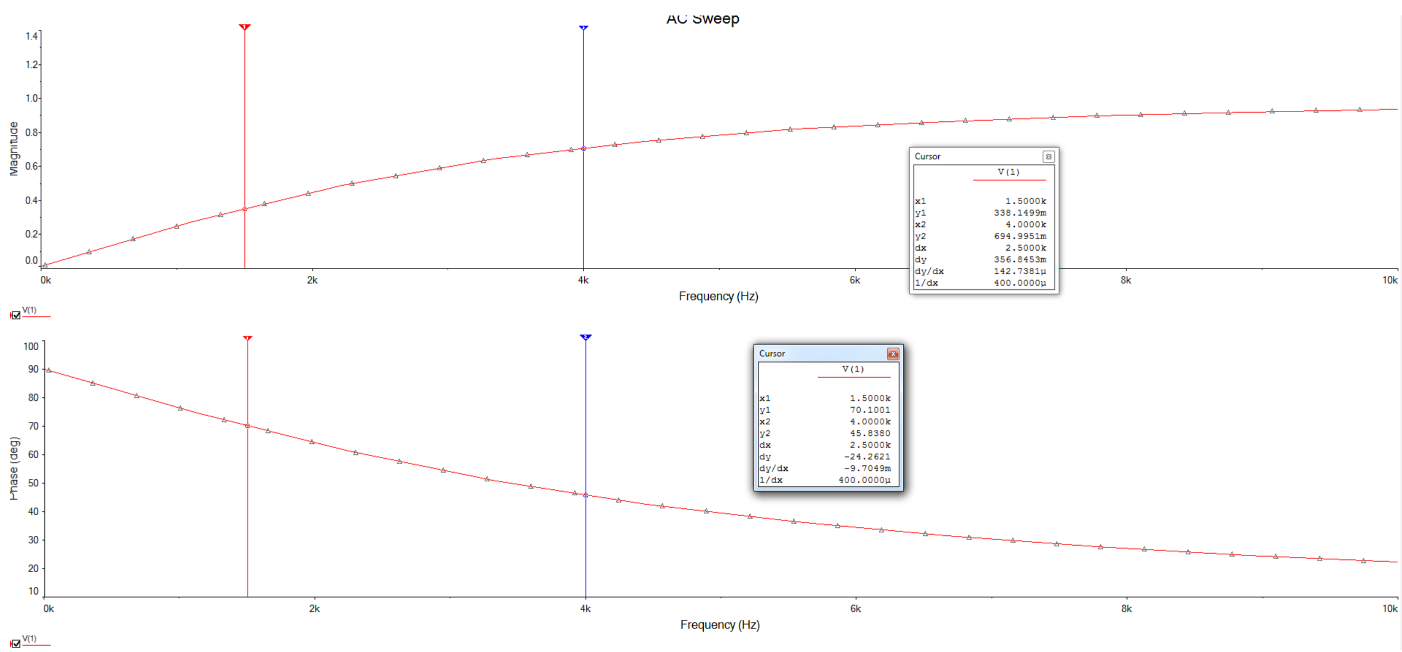
Values	R (Ω)	C (F)	3db attenuation freq (Hz)
Selected	3900	1.00×10^{-8}	4080.89598
Actual	3853.4	9.10×10^{-9}	4538.73

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

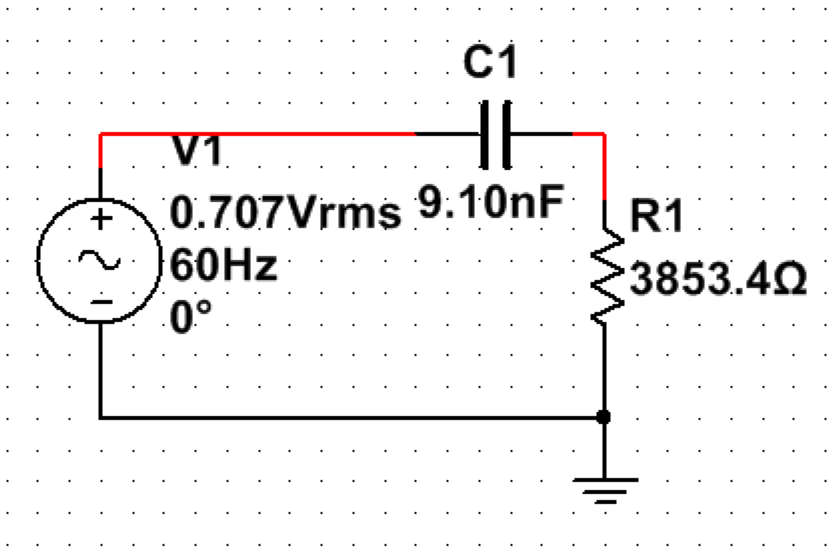
Simulation Schematic and Results:

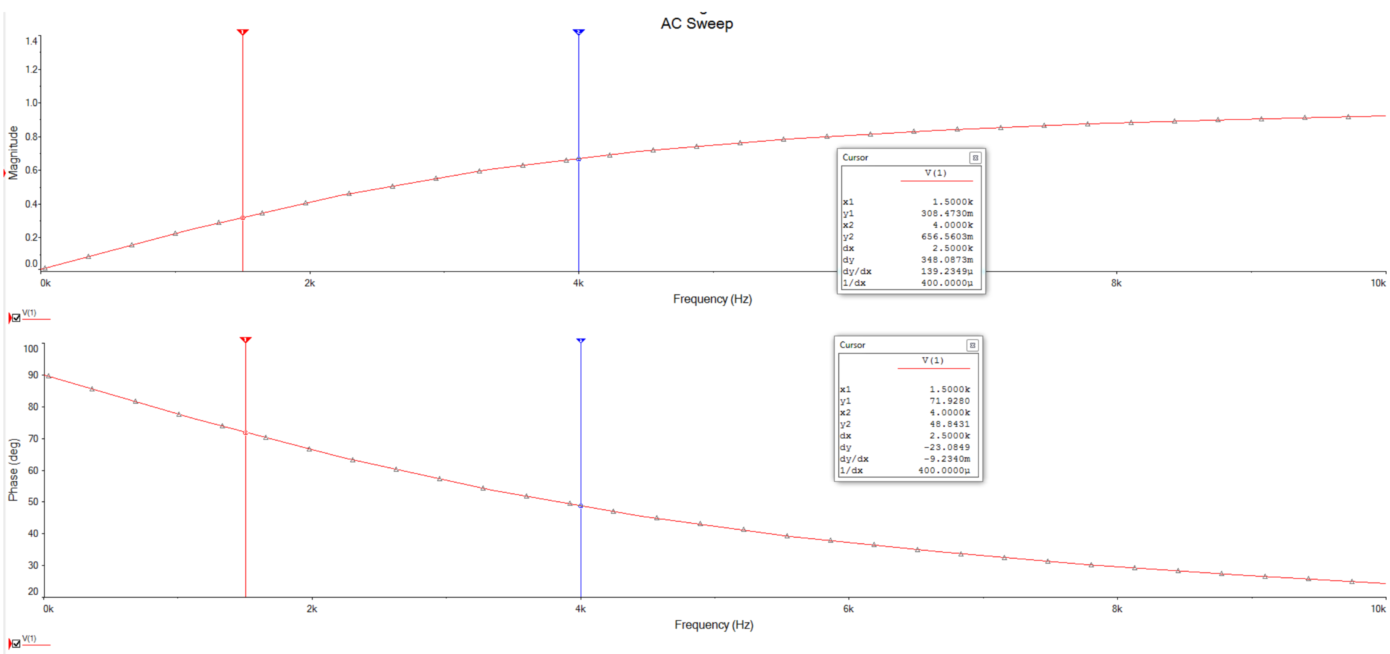
The theoretical circuit schematic and simulated sinusoidal sweep response from 1 Hz to 10 kHz is shown in the figures below. The simulation was performed in MultiSim.





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



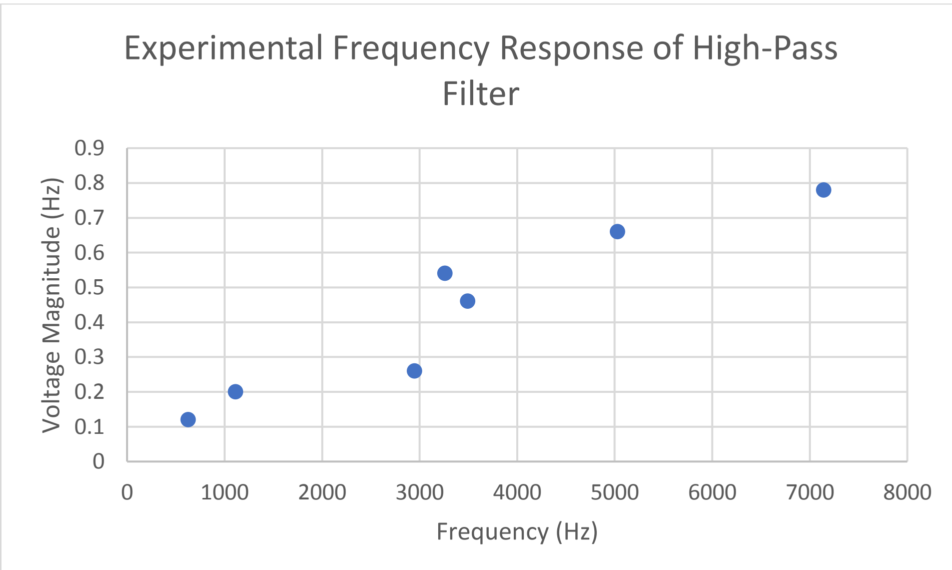


Experimental Results:

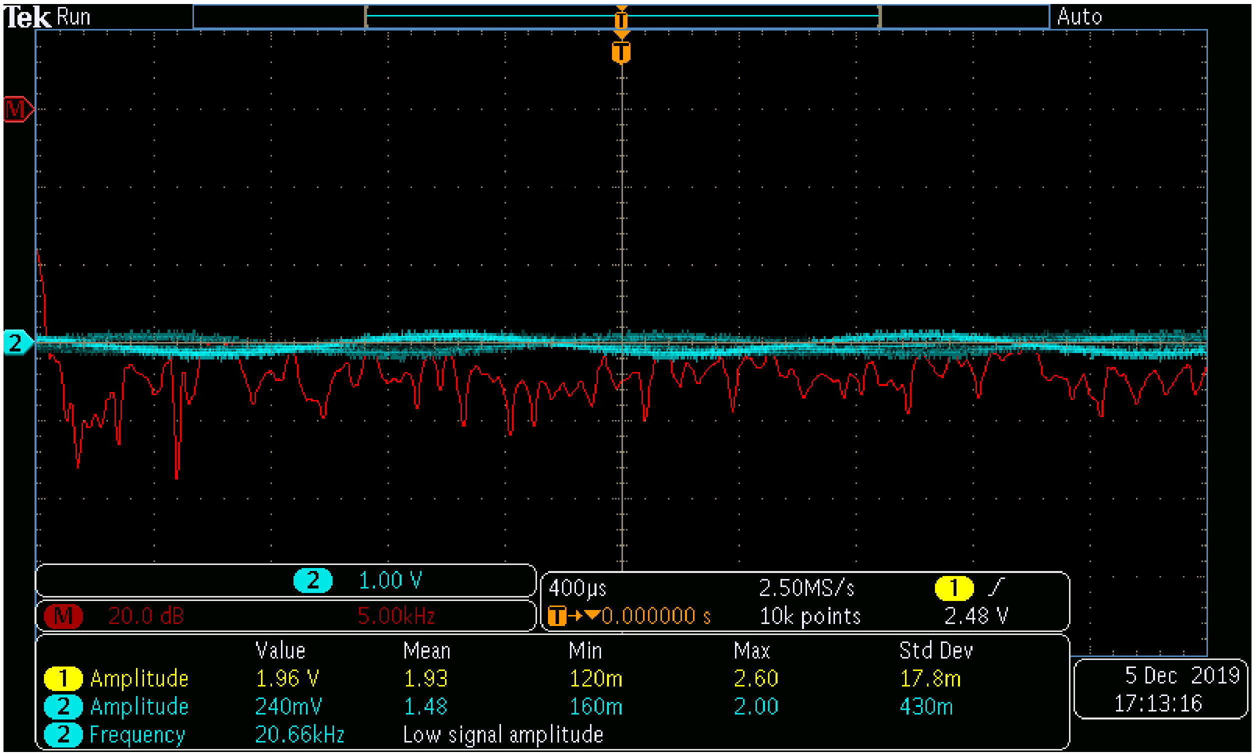
The following values were produced using the function generator set to sweep mode from 1 Hz to 10kHz with a sweep period of 15 seconds. The long sweep period was set to ensure that the oscilloscope could capture images of the waveforms at the passband and stopband frequencies. The values are tabulated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

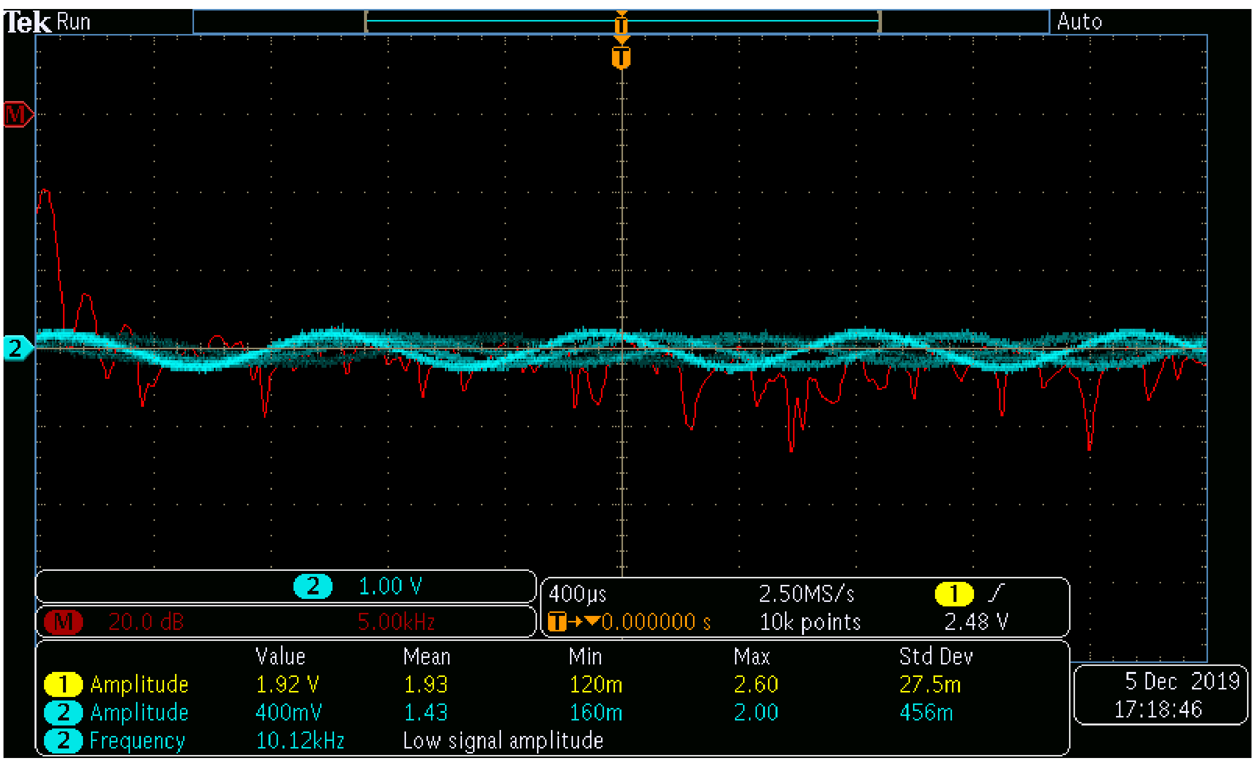
Frequency (Hz)	V_{mag} (V)
625*	0.12
1111*	0.2
2948	0.26
3259	0.54
3492	0.46
5028	0.66
7143	0.78

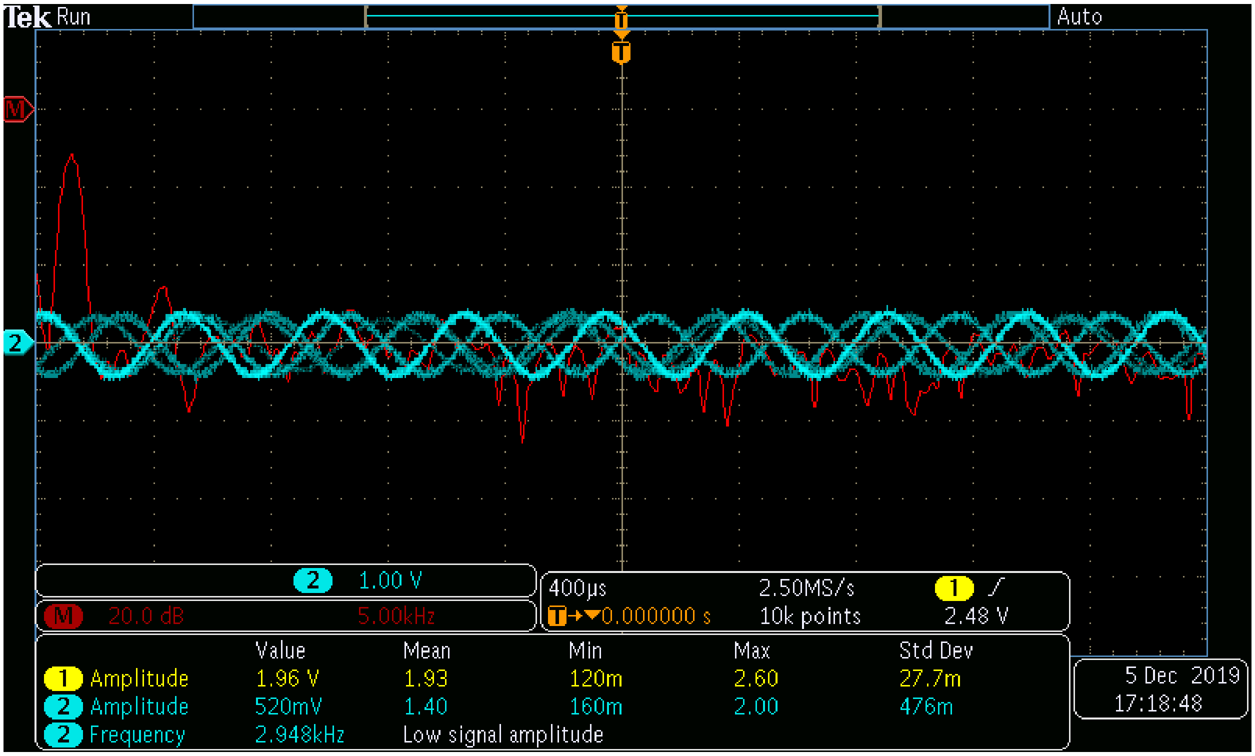
*these frequencies were computed by manual counting of the period due to measurement noise

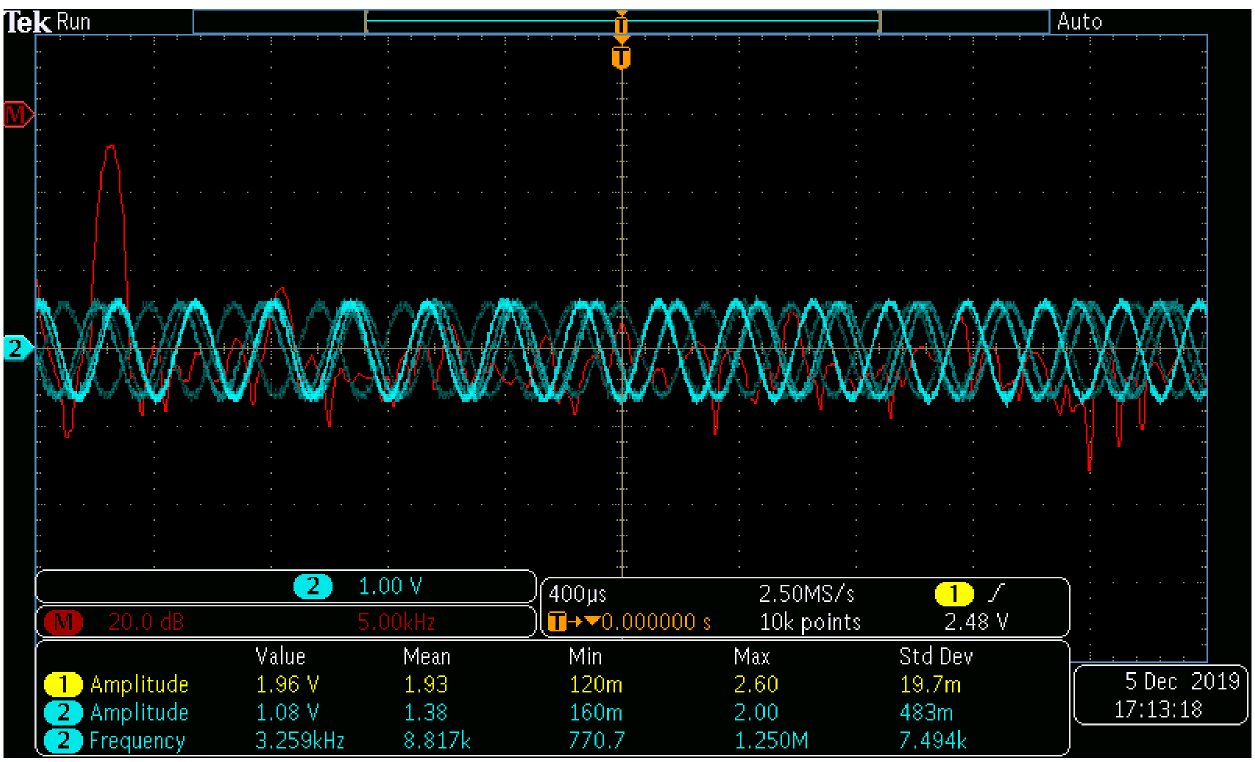


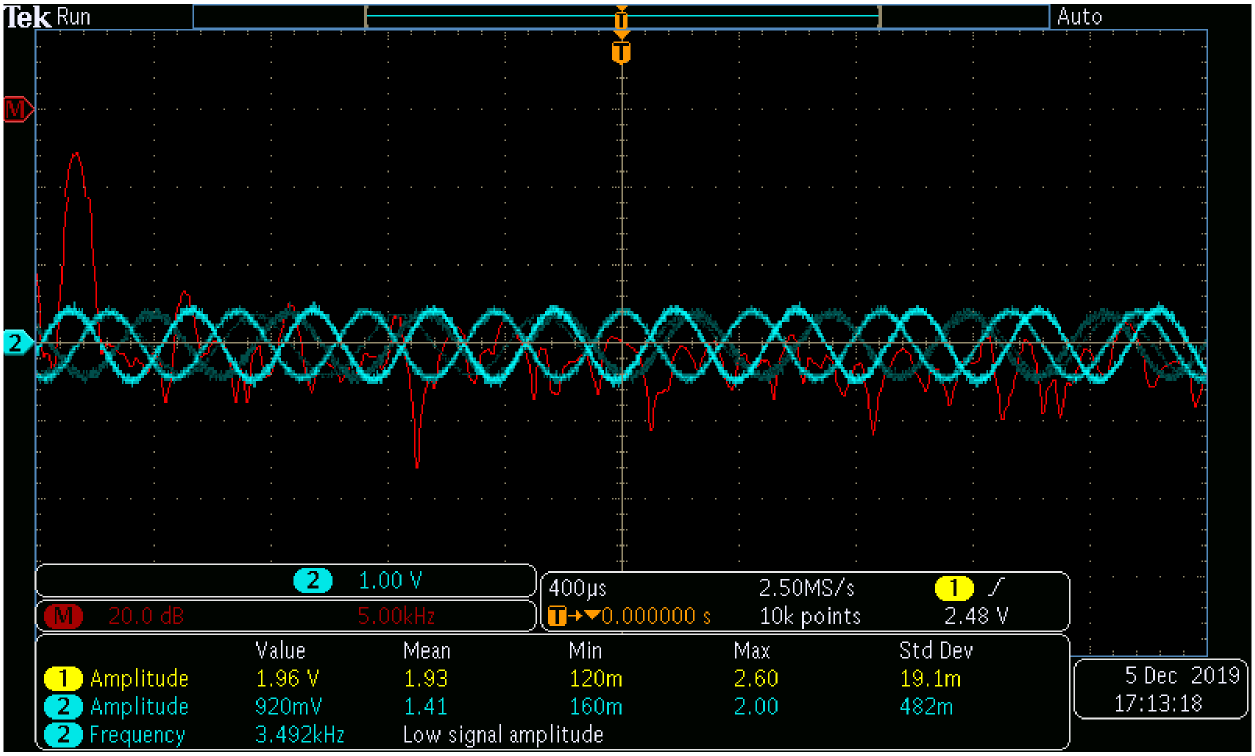
The oscilloscope screenshots below are in ascending order of frequency. The red graph displayed is the oscilloscope's built-in Fast Fourier Transform (FFT) function. However, the FFT graph is for reference purposes only, as the smallest resolution available is 5kHz per division, which is higher than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

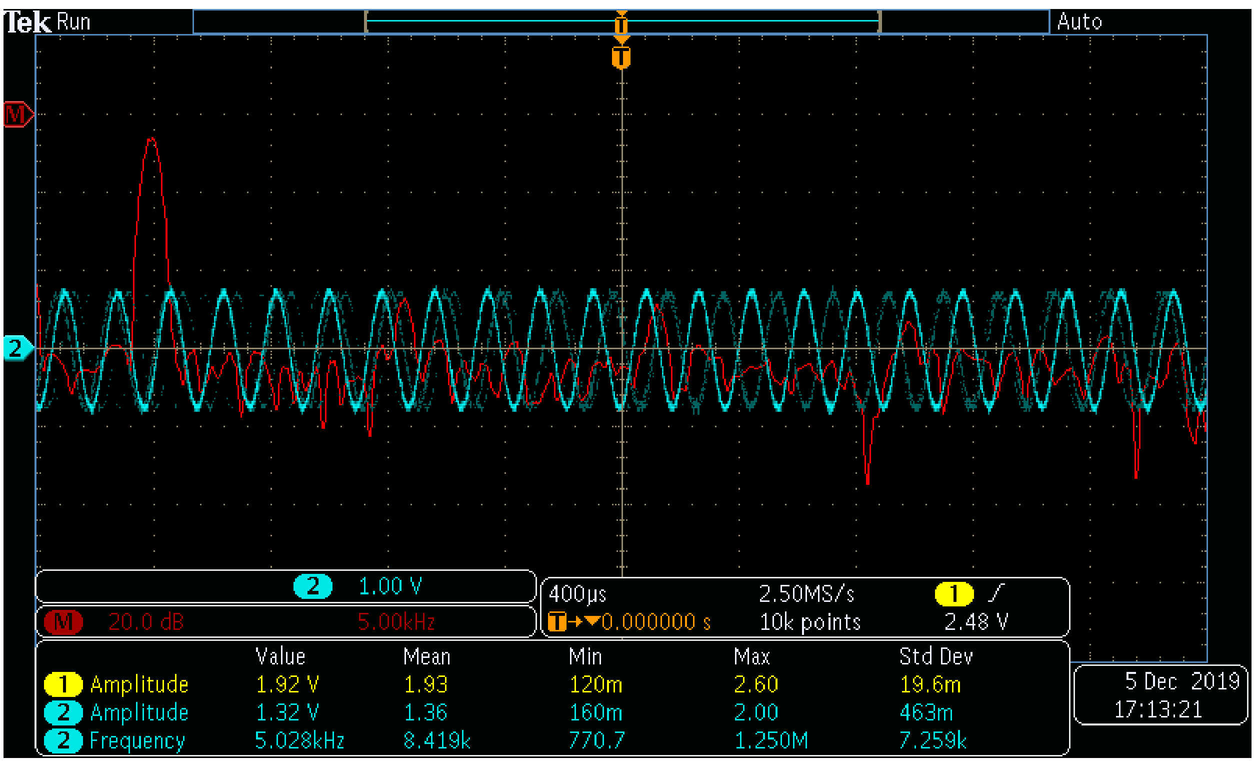

Tek Run
Auto
1.00 V
20.0 dB
5.00kHz
400µs
2.50MS/s
0.000000 s
10k points
2.48 V
Value Mean Min Max Std Dev
1 Amplitude 1.96 V 1.93 120m 2.60 17.8m
2 Amplitude 240mV 1.48 160m 2.00 430m
2 Frequency 20.66kHz Low signal amplitude
5 Dec 2019
17:13:16

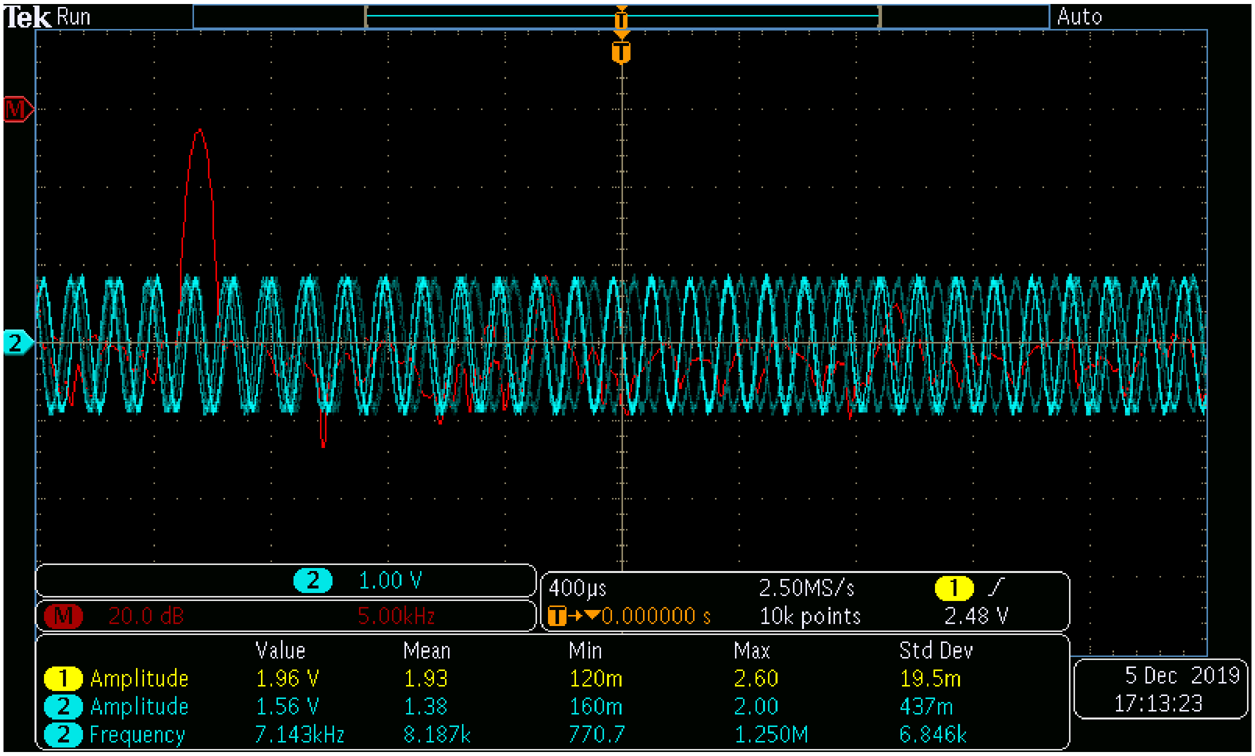

Tek Run
Auto
1.00 V
20.0 dB
5.00kHz
400µs
2.50MS/s
0.000000 s
10k points
2.48 V
Value Mean Min Max Std Dev
1 Amplitude 1.92 V 1.93 120m 2.60 27.5m
2 Amplitude 400mV 1.43 160m 2.00 456m
2 Frequency 10.12kHz Low signal amplitude
5 Dec 2019
17:18:46


Tek Run
Auto
M
2
2 1.00 V
M 20.0 dB 5.00kHz
400µs 2.50MS/s 1
T→▼0.000000 s 10k points 2.48 V
Value Mean Min Max Std Dev
1 Amplitude 1.96 V 1.93 120m 2.60 27.7m
2 Amplitude 520mV 1.40 160m 2.00 476m
2 Frequency 2.948kHz Low signal amplitude
5 Dec 2019
17:18:48


Tek Run
Auto
M
2
2 1.00 V
M 20.0 dB 5.00kHz
400µs 2.50MS/s 1
T→▼0.000000 s 10k points 2.48 V
Value Mean Min Max Std Dev
1 Amplitude 1.96 V 1.93 120m 2.60 19.7m
2 Amplitude 1.08 V 1.38 160m 2.00 483m
2 Frequency 3.259kHz 8.817k 770.7 1.250M 7.494k
5 Dec 2019
17:13:18


Tek Run
Auto
M
2
2 1.00 V
M 20.0 dB 5.00kHz
400µs 2.50MS/s 1 2.48 V
T→0.000000 s 10k points
Value Mean Min Max Std Dev
1 Amplitude 1.96 V 1.93 120m 2.60 19.1m
2 Amplitude 920mV 1.41 160m 2.00 482m
2 Frequency 3.492kHz Low signal amplitude
5 Dec 2019
17:13:18


Tek Run
Auto
M
2
2 1.00 V
M 20.0 dB 5.00kHz
400µs 2.50MS/s 1 2.48 V
T→0.000000 s 10k points
Value Mean Min Max Std Dev
1 Amplitude 1.92 V 1.93 120m 2.60 19.6m
2 Amplitude 1.32 V 1.36 160m 2.00 463m
2 Frequency 5.028kHz 8.419k 770.7 1.250M 7.259k
5 Dec 2019
17:13:21



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.

combined table

Src of edge values Nilsson, Riedel: Electric Circuits (10e), p. 761

R ↓ | C →	1E-11	2.2E-11	4.7E-11	1E-10	2.2E-10	4.7E-10	1E-09	2.2E-09	4.7E-09	1.00E-08	2.2E-08	4.7E-08	1.00E-07	0.00000022	0.00000047	0.000001	0.0000022	0.0000047	0.00001	0.000022	0.000047	0.0001	0.00022	0.00047	F
10	1591549431	723431560	338627538	159154943	72343156	33862753.8	15915494.3	7234315.6	3386275.38	1591549.43	723431.56	338627.538	159154.943	72343.156	33862.7538	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	
15	1061032954	482287706	225751692	106103295	48228770.6	22575169.2	10610329.5	4822877.06	2257516.92	1061032.95	482287.706	225751.692	106103.295	48228.7706	22575.1692	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	
22	723431560	328832527	153921608	72343156	32883252.7	15392160.8	7234315.6	3288325.27	1539216.08	723431.56	328832.527	153921.608	72343.156	32883.2527	15392.1608	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	
33	482287706	219221685	102614406	48228770.6	21922168.5	10261440.6	4822877.06	2192216.85	1026144.06	482287.706	219221.685	102614.406	48228.7706	21922.1685	10261.4406	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	
47	338627538	153921608	72048412.4	33862753.8	15392160.8	7204841.24	3386275.38	1539216.08	720484.124	338627.538	153921.608	72048.4124	33862.7538	15392.1608	7204.84124	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	
68	234051387	106386994	49798167.4	23405138.7	10638699.4	4979816.74	2340513.87	1063869.94	497981.674	234051.387	106386.994	49798.1674	23405.1387	10638.6994	4979.81674	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	
100	159154943	72343156	33862753.8	15915494.3	7234315.6	3386275.38	1591549.43	723431.56	338627.538	159154.943	72343.156	33862.7538	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	15.9154943	7.2343156	3.38627538	
120	132629119	60285963.3	28218961.5	13262911.9	6028596.33	2821896.15	1326291.19	602859.633	282189.615	132629.119	60285.9633	28218.9615	13262.9119	6028.59633	2821.89615	1326.29119	602.859633	282.189615	132.629119	60.2859633	28.2189615	13.2629119	6.02859633	2.82189615	
150	106103295	48228770.6	22575169.2	10610329.5	4822877.06	2257516.92	1061032.95	482287.706	225751.692	106103.295	48228.7706	22575.1692	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	10.6103295	4.82287706	2.25751692	
180	88419412.8	40190642.2	18812641	8841941.28	4019064.22	1881264.1	884194.128	401906.422	188126.41	88419.4128	40190.6422	18812.641	8841.94128	4019.06422	1881.2641	884.194128	401.906422	188.12641	88.4194128	40.1906422	18.812641	8.84194128	4.01906422	1.8812641	
220	72343156	32883252.7	15392160.8	7234315.6	3288325.27	1539216.08	723431.56	328832.527	153921.608	72343.156	32883.2527	15392.1608	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	7.2343156	3.28832527	1.53921608	
270	58946275.2	26793761.5	12541760.7	5894627.52	2679376.15	1254176.07	589462.752	267937.615	125417.607	58946.2752	26793.7615	12541.7607	5894.62752	2679.37615	1254.17607	589.462752	267.937615	125.417607	58.9462752	26.7937615	12.5417607	5.89462752	2.67937615	1.25417607	
330	48228770.6	21922168.5	10261440.6	4822877.06	2192216.85	1026144.06	482287.706	219221.685	102614.406	48228.7706	21922.1685	10261.4406	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	4.82287706	2.19221685	1.02614406	
390	40808959.8	18549527.2	8682757.4	4080895.98	1854952.72	868275.74	408089.598	185495.272	86827.574	40808.9598	18549.5272	8682.7574	4080.89598	1854.95272	868.27574	408.089598	185.495272	86.827574	40.8089598	18.5495272	8.6827574	4.08089598	1.85495272	0.86827574	
470	33862753.8	15392160.8	7204841.24	3386275.38	1539216.08	720484.124	338627.538	153921.608	72048.4124	33862.7538	15392.1608	7204.84124	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	3.38627538	1.53921608	0.72048412	
560	28420525.6	12918420.7	6046920.33	2842052.56	1291842.07	604692.033	284205.256	129184.207	60469.2033	28420.5256	12918.4207	6046.92033	2842.05256	1291.84207	604.692033	284.205256	129.184207	60.4692033	28.4205256	12.9184207	6.04692033	2.84205256	1.29184207	0.60469203	
680	23405138.7	10638699.4	4979816.74	2340513.87	1063869.94	497981.674	234051.387	106386.994	49798.1674	23405.1387	10638.6994	4979.81674	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	2.34051387	1.06386994	0.49798167	
1000	15915494.3	7234315.6	3386275.38	1591549.43	723431.56	338627.538	159154.943	72343.156	33862.7538	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	15.9154943	7.2343156	3.38627538	1.59154943	0.72343156	0.33862754	
1200	13262911.9	6028596.33	2821896.15	1326291.19	602859.633	282189.615	132629.119	60285.9633	28218.9615	13262.9119	6028.59633	2821.89615	1326.29119	602.859633	282.189615	132.629119	60.2859633	28.2189615	13.2629119	6.02859633	2.82189615	1.32629119	0.60285963	0.28218962	
1500	10610329.5	4822877.06	2257516.92	1061032.95	482287.706	225751.692	106103.295	48228.7706	22575.1692	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	10.6103295	4.82287706	2.25751692	1.06103295	0.48228771	0.22575169	
1800	8841941.28	4019064.22	1881264.1	884194.128	401906.422	188126.41	88419.4128	40190.6422	18812.641	8841.94128	4019.06422	1881.2641	884.194128	401.906422	188.12641	88.4194128	40.1906422	18.812641	8.84194128	4.01906422	1.8812641	0.88419413	0.40190642	0.18812641	
2200	7234315.6	3288325.27	1539216.08	723431.56	328832.527	153921.608	72343.156	32883.2527	15392.1608	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	7.2343156	3.28832527	1.53921608	0.72343156	0.32883253	0.15392161	
2700	5894627.52	2679376.15	1254176.07	589462.752	267937.615	125417.607	58946.2752	26793.7615	12541.7607	5894.62752	2679.37615	1254.17607	589.462752	267.937615	125.417607	58.9462752	26.7937615	12.5417607	5.89462752	2.67937615	1.25417607	0.58946275	0.26793761	0.12541761	
3300	4822877.06	2192216.85	1026144.06	482287.706	219221.685	102614.406	48228.7706	21922.1685	10261.4406	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	4.82287706	2.19221685	1.02614406	0.48228771	0.21922168	0.10261441	
3900	4080895.98	1854952.72	868275.74	408089.598	185495.272	86827.574	40808.9598	18549.5272	8682.7574	4080.89598	1854.95272	868.27574	408.089598	185.495272	86.827574	40.8089598	18.5495272	8.6827574	4.08089598	1.85495272	0.86827574	0.4080896	0.18549527	0.08682757	
4700	3386275.38	1539216.08	720484.124	338627.538	153921.608	72048.4124	33862.7538	15392.1608	7204.84124	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	3.38627538	1.53921608	0.72048412	0.33862754	0.15392161	0.07204841	
5600	2842052.56	1291842.07	604692.033	284205.256	129184.207	60469.2033	28420.5256	12918.4207	6046.92033	2842.05256	1291.84207	604.692033	284.205256	129.184207	60.4692033	28.4205256	12.9184207	6.04692033	2.84205256	1.29184207	0.60469203	0.28420526	0.12918421	0.0604692	
6800	2340513.87	1063869.94	497981.674	234051.387	106386.994	49798.1674	23405.1387	10638.6994	4979.81674	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	2.34051387	1.06386994	0.49798167	0.23405139	0.10638699	0.04979817	
10000	1591549.43	723431.56	338627.538	159154.943	72343.156	33862.7538	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	15.9154943	7.2343156	3.38627538	1.59154943	0.72343156	0.33862754	0.15915494	0.07234316	0.03386275	
12000	1326291.19	602859.633	282189.615	132629.119	60285.9633	28218.9615	13262.9119	6028.59633	2821.89615	1326.29119	602.859633	282.189615	132.629119	60.2859633	28.2189615	13.2629119	6.02859633	2.82189615	1.32629119	0.60285963	0.28218962	0.13262912	0.06028596	0.02821896	
15000	1061032.95	482287.706	225751.692	106103.295	48228.7706	22575.1692	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	10.6103295	4.82287706	2.25751692	1.06103295	0.48228771	0.22575169	0.1061033	0.04822877	0.02257517	
18000	884194.128	401906.422	188126.41	88419.4128	40190.6422	18812.641	8841.94128	4019.06422	1881.2641	884.194128	401.906422	188.12641	88.4194128	40.1906422	18.812641	8.84194128	4.01906422	1.8812641	0.88419413	0.40190642	0.18812641	0.08841941	0.04019064	0.01881264	
22000	723431.56	328832.527	153921.608	72343.156	32883.2527	15392.1608	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	7.2343156	3.28832527	1.53921608	0.72343156	0.32883253	0.15392161	0.07234316	0.03288325	0.01539216	
27000	589462.752	267937.615	125417.607	58946.2752	26793.7615	12541.7607	5894.62752	2679.37615	1254.17607	589.462752	267.937615	125.417607	58.9462752	26.7937615	12.5417607	5.89462752	2.67937615	1.25417607	0.58946275	0.26793761	0.12541761	0.05894628	0.02679376	0.01254176	
33000	482287.706	219221.685	102614.406	48228.7706	21922.1685	10261.4406	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	4.82287706	2.19221685	1.02614406	0.48228771	0.21922168	0.10261441	0.04822877	0.02192217	0.01026144	
39000	408089.598	185495.272	86827.574	40808.9598	18549.5272	8682.7574	4080.89598	1854.95272	868.27574	408.089598	185.495272	86.827574	40.8089598	18.5495272	8.6827574	4.08089598	1.85495272	0.86827574	0.4080896	0.18549527	0.08682757	0.04080896	0.01854953	0.00868276	
47000	338627.538	153921.608	72048.4124	33862.7538	15392.1608	7204.84124	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	3.38627538	1.53921608	0.72048412	0.33862754	0.15392161	0.07204841	0.03386275	0.01539216	0.00720484	
56000	284205.256	129184.207	60469.2033	28420.5256	12918.4207	6046.92033	2842.05256	1291.84207	604.692033	284.205256	129.184207	60.4692033	28.4205256	12.9184207	6.04692033	2.84205256	1.29184207	0.60469203	0.28420526	0.12918421	0.0604692	0.02842053	0.01291842	0.00604692	

68000	234051.387	106386.994	49798.1674	23405.1387	10638.6994	4979.81674	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	2.34051387	1.06386994	0.49798167	0.23405139	0.10638699	0.04979817	0.02340514	0.0106387	0.00497982
100000	159154.943	72343.156	33862.7538	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	15.9154943	7.2343156	3.38627538	1.59154943	0.72343156	0.33862754	0.15915494	0.07234316	0.03386275	0.01591549	0.00723432	0.00338628
120000	132629.119	60285.9633	28218.9615	13262.9119	6028.59633	2821.89615	1326.29119	602.859633	282.189615	132.629119	60.2859633	28.2189615	13.2629119	6.02859633	2.82189615	1.32629119	0.60285963	0.28218962	0.13262912	0.06028596	0.02821896	0.01326291	0.0060286	0.0028219
150000	106103.295	48228.7706	22575.1692	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	10.6103295	4.82287706	2.25751692	1.06103295	0.48228771	0.22575169	0.1061033	0.04822877	0.02257517	0.01061033	0.00482288	0.00225752
180000	88419.4128	40190.6422	18812.641	8841.94128	4019.06422	1881.2641	884.194128	401.906422	188.12641	88.4194128	40.1906422	18.812641	8.84194128	4.01906422	1.8812641	0.88419413	0.40190642	0.18812641	0.08841941	0.04019064	0.01881264	0.00884194	0.00401906	0.00188126
220000	72343.156	32883.2527	15392.1608	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	7.2343156	3.28832527	1.53921608	0.72343156	0.32883253	0.15392161	0.07234316	0.03288325	0.01539216	0.00723432	0.00328833	0.00153922
270000	58946.2752	26793.7615	12541.7607	5894.62752	2679.37615	1254.17607	589.462752	267.937615	125.417607	58.9462752	26.7937615	12.5417607	5.89462752	2.67937615	1.25417607	0.58946275	0.26793761	0.12541761	0.05894628	0.02679376	0.01254176	0.00589463	0.00267938	0.00125418
330000	48228.7706	21922.1685	10261.4406	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	4.82287706	2.19221685	1.02614406	0.48228771	0.21922168	0.10261441	0.04822877	0.02192217	0.01026144	0.00482288	0.00219222	0.00102614
390000	40808.9598	18549.5272	8682.7574	4080.89598	1854.95272	868.27574	408.089598	185.495272	86.827574	40.8089598	18.5495272	8.6827574	4.08089598	1.85495272	0.86827574	0.4080896	0.18549527	0.08682757	0.04080896	0.01854953	0.00868276	0.0040809	0.00185495	0.00086828
470000	33862.7538	15392.1608	7204.84124	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	3.38627538	1.53921608	0.72048412	0.33862754	0.15392161	0.07204841	0.03386275	0.01539216	0.00720484	0.00338628	0.00153922	0.00072048
560000	28420.5256	12918.4207	6046.92033	2842.05256	1291.84207	604.692033	284.205256	129.184207	60.4692033	28.4205256	12.9184207	6.04692033	2.84205256	1.29184207	0.60469203	0.28420526	0.12918421	0.0604692	0.02842053	0.01291842	0.00604692	0.00284205	0.00129184	0.00060469
680000	23405.1387	10638.6994	4979.81674	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	2.34051387	1.06386994	0.49798167	0.23405139	0.10638699	0.04979817	0.02340514	0.0106387	0.00497982	0.00234051	0.00106387	0.00049798
1000000	15915.4943	7234.3156	3386.27538	1591.54943	723.43156	338.627538	159.154943	72.343156	33.8627538	15.9154943	7.2343156	3.38627538	1.59154943	0.72343156	0.33862754	0.15915494	0.07234316	0.03386275	0.01591549	0.00723432	0.00338628	0.00159155	0.00072343	0.00033863
1500000	10610.3295	4822.87706	2257.51692	1061.03295	482.287706	225.751692	106.103295	48.2287706	22.5751692	10.6103295	4.82287706	2.25751692	1.06103295	0.48228771	0.22575169	0.1061033	0.04822877	0.02257517	0.01061033	0.00482288	0.00225752	0.00106103	0.00048229	0.00022575
2200000	7234.3156	3288.32527	1539.21608	723.43156	328.832527	153.921608	72.343156	32.8832527	15.3921608	7.2343156	3.28832527	1.53921608	0.72343156	0.32883253	0.15392161	0.07234316	0.03288325	0.01539216	0.00723432	0.00328833	0.00153922	0.00072343	0.00032883	0.00015392
3300000	4822.87706	2192.21685	1026.14406	482.287706	219.221685	102.614406	48.2287706	21.9221685	10.2614406	4.82287706	2.19221685	1.02614406	0.48228771	0.21922168	0.10261441	0.04822877	0.02192217	0.01026144	0.00482288	0.00219222	0.00102614	0.00048229	0.00021922	0.00010261
4700000	3386.27538	1539.21608	720.484124	338.627538	153.921608	72.0484124	33.8627538	15.3921608	7.20484124	3.38627538	1.53921608	0.72048412	0.33862754	0.15392161	0.07204841	0.03386275	0.01539216	0.00720484	0.00338628	0.00153922	0.00072048	0.00033863	0.00015392	7.2048E-05
6800000	2340.51387	1063.86994	497.981674	234.051387	106.386994	49.7981674	23.4051387	10.6386994	4.97981674	2.34051387	1.06386994	0.49798167	0.23405139	0.10638699	0.04979817	0.02340514	0.0106387	0.00497982	0.00234051	0.00106387	0.00049798	0.00023405	0.00010639	4.9798E-05

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