Build Your LC Filter with the Coilcraft Reference Design

LC Filter Reference Design uses off-the-shelf components

LC filters are widely used in many applications to provide a variety of frequency characteristics. While passive filters may seem simpler in concept than active filters, design and performance verification can still be a time consuming process, involving some trial and error. To simplify LC filter design, especially high order filters that require more complex computations, Coilcraft has created LC filter reference design evaluation modules, including 3rd order Butterworth low-pass and high-pass, as well as 7th order elliptic. These modules demonstrate the high performance that can be achieved using Coilcraft inductors and standard capacitors.

LC Filters are classified as low-pass, high-pass, band-pass, and band-stop. They can be identified by their particular frequency response characteristics, including Butterworth, Chebyshev, Bessel, and Elliptic. Each has certain advantages and disadvantages and represents various trade-offs between the pass-band ripple and stop-band attenuation.

Benefits of Coilcraft Reference Design

Free filter design programs are available that provide ideal element component values that can be used when starting an LC filter design. One such program, *Design LC filter,* is available at http://www.wa4dsy.net/filter/filterdesign.html. For example, to achieve a 3rd order low-pass LC filter providing the cutoff frequency at 1200 MHz, the program suggests the ideal model with component values L1, L2 = 6.6 nH and C1 = 5.31 pF (see Figure 1). These values can be used as a starting point for the real filter design. However, without considering component and PCB parasitics, they may not be very close to real-world performance, resulting in a time consuming process of tuning and adjusting, particularly for the high cutoff frequency filters.

For a high performance design example including component parasitic effects and PCB board parasitic interactions of the components with the circuit board, Coilcraft offers 3rd order Butterworth low-pass filter reference designs. The Butterworth low-pass filter uses two 3.9 nH 0805HT Series inductors and a 3.6 pF capacitor targeting a 1200 MHz cutoff frequency. The frequency response of the filter measured with the LC components mounted on a 25 mil thick ceramic substrate yields a cutoff frequency of approximately 1100 MHz. The difference between the calculated value and the real measurement reflects the component parasitic effects and the circuit board effects.

On the other hand, simulating the design including the inductor parasitics by using s-parameters predicts a cutoff frequency of 1700 MHz (Figure 2), which is not particularly close. This suggests the non-ideal PCB characteristics and parasitic arising from the connection of the components to the PCB are significant and must be included to make the model complete. In any event, the reference design measurements provide a handy, accurate, real-world picture of filter performance

Third Order Butterworth Reference Design (page 4)

The 3rd order Butterworth LC low-pass and high-pass filters are two common types. The frequency response of the Butterworth filter has the least pass-band ripple.

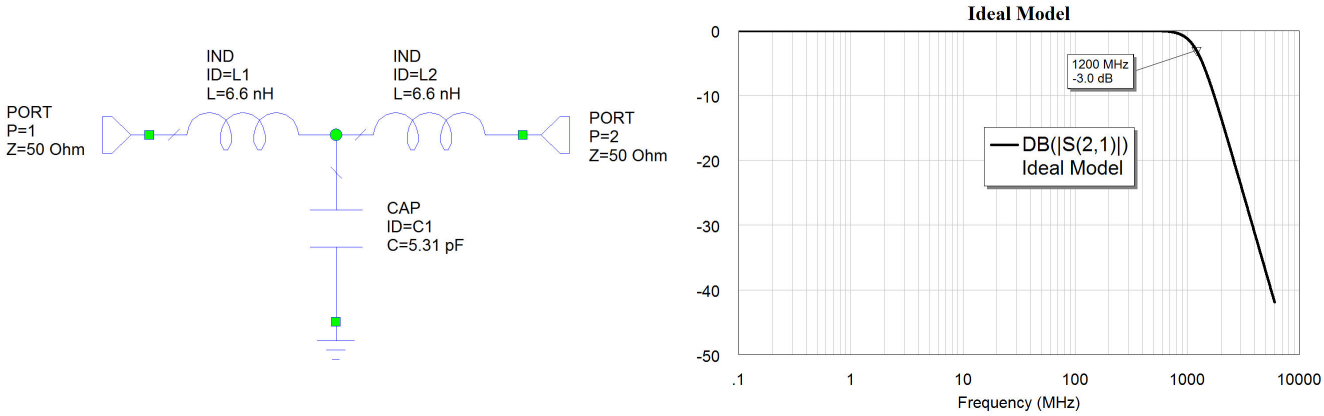
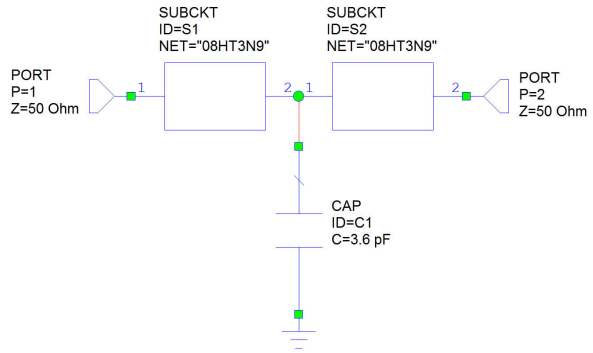


Figure 1.



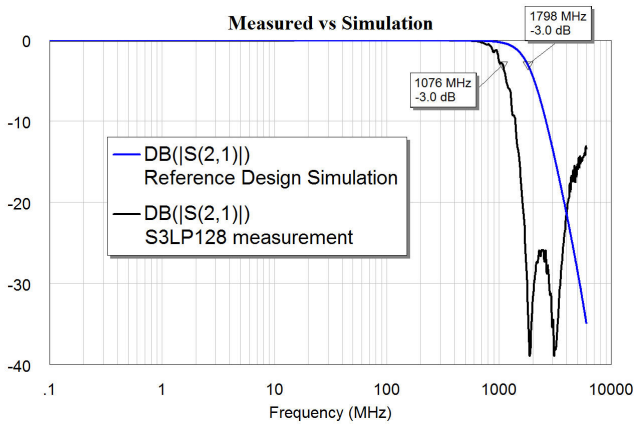


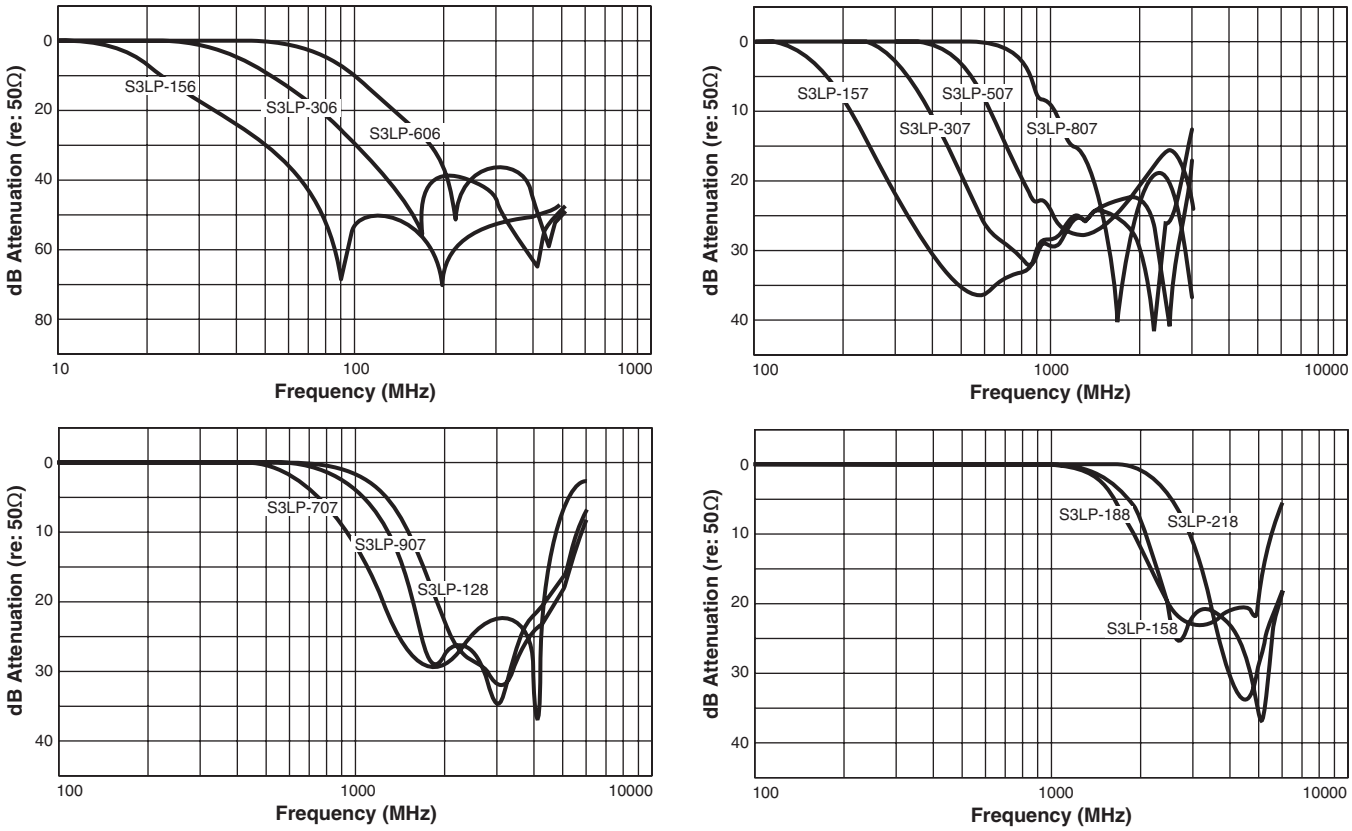
Figure 2.

The inductors selected for 3rd order Butterworth reference designs are off-the-shelf Coilcraft 0805HT series. These wirewound ceramic chip inductors are low profile (only 0.035 inch high) and have a small footprint, offering tremendous board space saving. The 0805HT has tight tolerance at 2% to ensure that the required performance is obtained. The designs feature 50 Ohm characteristic impedance and less than 0.3 dB insertion loss.

The 3rd order low-pass filters reference design provides a wide range of cut-off frequencies from 3 MHz to 3 GHz. For 3-pole high-pass filter, 15 MHz to 900 MHz cutoff frequencies could be obtained. User may simply order the part number in the reference design BOM list to get the closest component values for the design requirements.

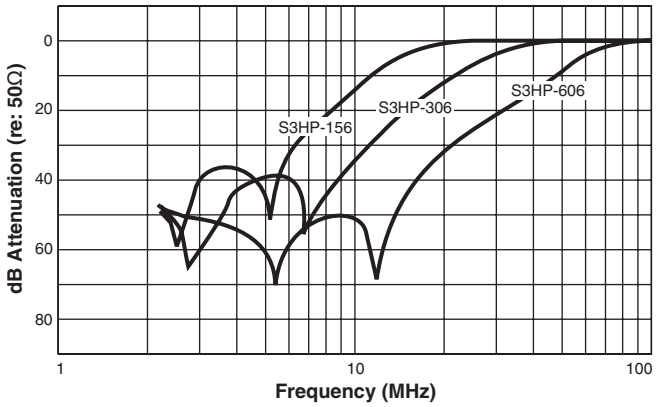
The designer may modify or enhance the filter design based on Coilcraft reference design (e.g., by using larger inductors to achieve improved performance). Coilcraft offers a wide range of off-the-shelf inductors that designers can choose from.

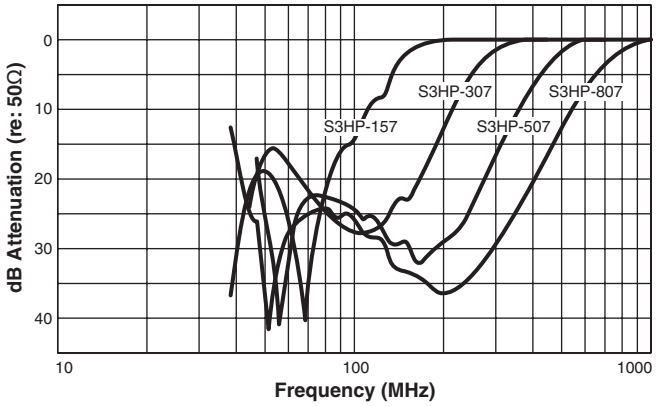
Frequency Response – 3 Pole Low-Pass Filters*



*Measured on Agilent/HP 8753D network analyzer (re: 50Ω)

Frequency Response – 3 Pole High Pass Filters*





Seventh Order Elliptic Filter Reference Design (page 5)

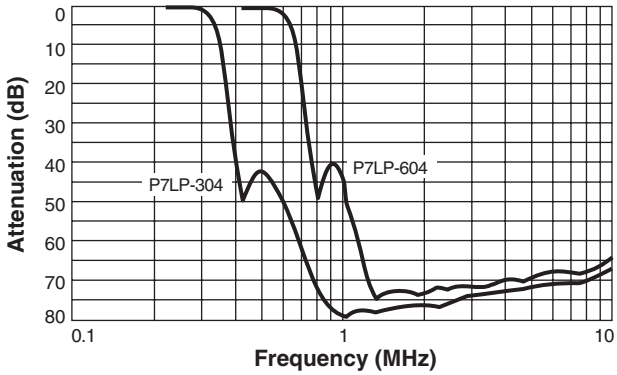
Compared to a Butterworth filter, elliptic filters have equalized ripple in both the passband and the stop-band. However, for the same order level, it has the fastest transition between passband and the stop-band. Coilcraft offers 7th order elliptic reference designs with less than 0.3 dB insertion loss and 50-Ohm characteristic impedance. The off-the-shelf selection of inductors is our 1812LS Series ferrite chip inductor. The tolerance is as low as 5%. These seventh order elliptic lowpass filters offer sharp roll-off rate at 80 dB/dec and wide range of cutoff frequencies from 0.3 MHz to 500 MHz.

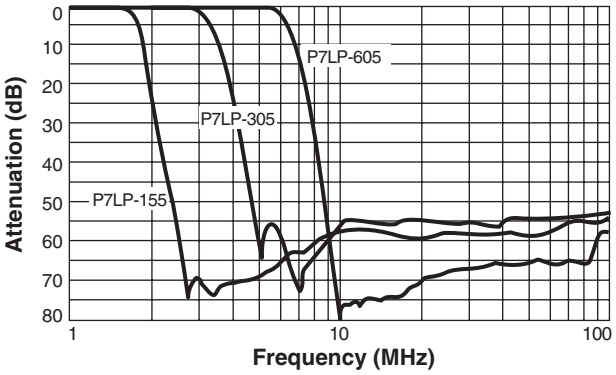
Summary

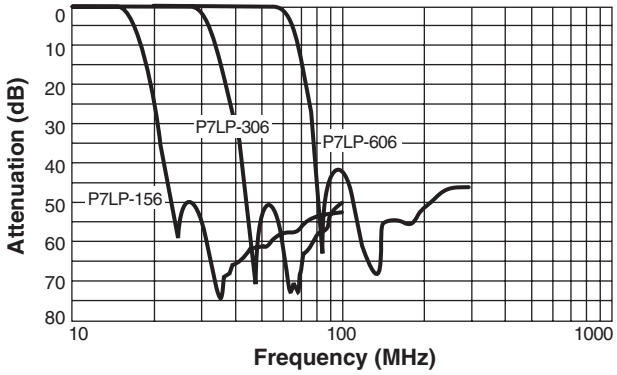
Typically, a passive LC filter design starts with calculations and then a very iterative trial-and-error process.

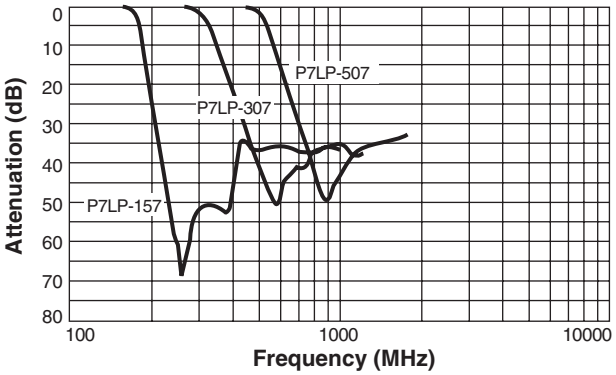
Coilcraft LC filter reference designs can save time, effort and cost for LC passive filter designers, allowing them to better select the right components and achieve desired performance. The reference designs included in this app note include BOMs of standard off-the-shelf inductors and capacitor values. For further discussion of the LC filter design program and inductor models, refer to the application note "Passive LC Filter Design and Analysis".

Frequency Response – 7 Pole Filters*









*Measured on Agilent/HP 8753D network analyzer (re: 50Ω)

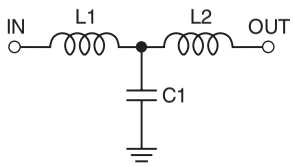
LC Filter Circuit Design

Designing low- and high-pass filters using off-the shelf components

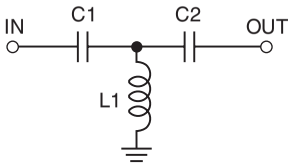
These low and high pass filter circuits serve a wide variety of filtering requirements. The design features 3rd order Butterworth alignment, 50 Ohm characteristic impedance and low insertion loss.

The S3LP and S3HP modules incorporate the components of this design into 1812-size surface mount packages.

Low pass filter



High pass filter



3-Pole Low Pass Filters

–3 dB cutoff (MHz)	L1 part number	L2 part number	L1 (nH)	L2 (nH)	C1 ±2% (pF)	Coilcraft low pass filter part number
3	0805HT-R79TGLB	0805HT-R79TGLB	790 ±2%	790 ±2%	2400	S3LP305L
6	0805HT-R79TGLB	0805HT-R79TGLB	790 ±2%	790 ±2%	1200	S3LP605L
10	0805HT-R63TGLB	0805HT-R63TGLB	630 ±2%	630 ±2%	680	S3LP106L
13	0805HT-R63TGLB	0805HT-R63TGLB	630 ±2%	630 ±2%	470	S3LP136L
15	0805HT-R50TGLB	0805HT-R50TGLB	500 ±2%	500 ±2%	390	S3LP156L
30	0805HT-R18TGLB	0805HT-R18TGLB	180 ±2%	180 ±2%	220	S3LP306L
45	0805HT-R18TGLB	0805HT-R18TGLB	180 ±2%	180 ±2%	120	S3LP456L
60	0805HT-R12TGLB	0805HT-R12TGLB	120 ±2%	120 ±2%	100	S3LP606L
70	0805HT-R10TGLB	0805HT-R10TGLB	100 ±2%	100 ±2%	91	S3LP706L
95	0805HT-72NTGLB	0805HT-72NTGLB	72 ±2%	72 ±2%	62	S3LP956L
100	0805HT-68NTGLB	0805HT-68NTGLB	68 ±2%	68 ±2%	56	S3LP107L
110	0805HT-68NTGLB	0805HT-68NTGLB	68 ±2%	68 ±2%	56	S3LP117L
150	0805HT-68NTGLB	0805HT-68NTGLB	68 ±2%	68 ±2%	33	S3LP157L
200	0805HT-33NTGLB	0805HT-33NTGLB	33 ±2%	33 ±2%	30	S3LP207L
230	0805HT-33NTGLB	0805HT-33NTGLB	33 ±2%	33 ±2%	24	S3LP237L
300	0805HT-33NTGLB	0805HT-33NTGLB	33 ±2%	33 ±2%	15	S3LP307L
350	0805HT-18NTGLB	0805HT-18NTGLB	18 ±2%	18 ±2%	15	S3LP357L
400	0805HT-17NTGLB	0805HT-17NTGLB	17 ±2%	17 ±2%	12	S3LP407L
450	0805HT-18NTGLB	0805HT-18NTGLB	18 ±2%	18 ±2%	10	S3LP457L
500	0805HT-18NTGLB	0805HT-18NTGLB	18 ±2%	18 ±2%	9.1	S3LP507L
700	0805HT-8N2TGLB	0805HT-8N2TGLB	8.2 ±2%	8.2 ±2%	6.8	S3LP707L
800	0805HT-8N2TGLB	0805HT-8N2TGLB	8.2 ±2%	8.2 ±2%	5.6	S3LP807L
900	0805HT-4N7TGLB	0805HT-4N7TGLB	4.7 ±2%	4.7 ±2%	5.6	S3LP907L
1000	0805HT-3N9TGLB	0805HT-3N9TGLB	3.9 ±2%	3.9 ±2%	4.7	S3LP108L
1200	0805HT-3N9TGLB	0805HT-3N9TGLB	3.9 ±2%	3.9 ±2%	3.6	S3LP128L
1500	0805HT-3N9TGLB	0805HT-3N9TGLB	3.9 ±2%	3.9 ±2%	2.7	S3LP158L
1600	0805HT-2N2TJLB	0805HT-2N2TJLB	2.2 ±5%	1.8 ±5%	2.7	S3LP168L
1800	0805HT-1N8TJLB	0805HT-1N8TJLB	1.8 ±5%	1.8 ±5%	2.0	S3LP188L
2000	0805HT-1N8TJLB	0805HT-1N8TJLB	1.8 ±5%	1.8 ±5%	1.5	S3LP218L
2600	0805HT-1N8TJLB	0805HT-1N8TJLB	1.8 ±5%	1.8 ±5%	1.0	S3LP268L
3000	0805HT-1N8TJLB	0805HT-1N8TJLB	1.8 ±5%	1.8 ±5%	0.5	S3LP308L

3-Pole High Pass Filters

–3 dB cutoff (MHz)	L1 part number	L1 ±2% (nH)	C1 ±2% (pF)	C2 ±2% (pF)	Coilcraft high pass filter part number
15	0805HT-R22TGLB	220	330	390	S3HP156L
30	0805HT-R18TGLB	180	68	68	S3HP306L
60	0805HT-68NTGLB	68	56	56	S3HP606L
100	0805HT-39NTGLB	39	39	39	S3HP107L
150	0805HT-27NTGLB	27	20	20	S3HP157L
300	0805HT-15NTGLB	15	6.8	6.8	S3HP307L
500	0805HT-6N8TGLB	6.8	5.6	5.6	S3HP507L
700	0805HT-3N9TGLB	3.9	4.5	4.5	S3HP707L
800	0805HT-3N9TGLB	3.9	3.0	3.0	S3HP807L
900	0805HT-3N9TGLB	3.9	2.2	2.2	S3HP907L

Notes:

All values are for reference only. Layout and substrate affect final performance.

3rd order Butterworth filter (refer to schematics). Ref. 50 Ohms.

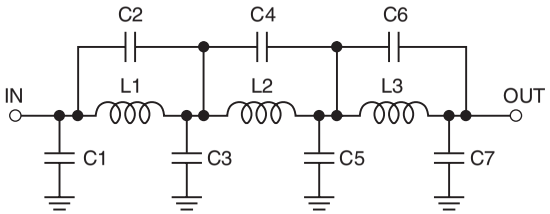
Improved performance may be achieved by using other (typically larger) inductors. Use the RF Inductor Finder tool to find alternatives.

LC Filter Circuit Design

Designing low- and high-pass filters using off-the shelf components

These low-pass filter circuits serve a wide variety of filtering requirements. The design features 7th order elliptic alignment, 50 Ohm characteristic impedance and low insertion loss.

The P7LP modules incorporate the components of this design.



7-Pole Low Pass Filters

–3 dB cutoff (MHz)	L1 part number	L2 part number	L3 part number	L1 ±5% (nH)	L2 ±5% (nH)	L3 ±5% (nH)	C1 ±5% (pF)	C2 ±5% (pF)	C3 ±5% (pF)	C4 ±5% (pF)	C5 ±5% (pF)	C6 ±5% (pF)	C7 ±5% (pF)	Coilcraft low pass filter part number
0.30	1812LS-333XJLB	1812LS-333XJLB	1812LS-273XJLB	33000	33000	27000	6800	510	15000	3300	15000	1500	5600	P7LP-304L
0.50	1812LS-183XJLB	1812LS-223XJLB	1812LS-183XJLB	18000	22000	18000	3300	270	6800	1800	6800	910	2200	P7LP-504L
0.60	1812LS-183XJLB	1812LS-183XJLB	1812LS-153XJLB	18000	18000	15000	3300	270	6800	1800	6800	910	2200	P7LP-604L
0.62	1008LS-153XJLB	1008LS-153XJLB	1008LS-153XJLB	15000	15000	15000	3300	240	6800	1000	6800	910	2200	P7LP-624L
0.80	1812LS-123XJLB	1812LS-123XJLB	1812LS-153XJLB	12000	12000	15000	2200	150	5600	750	5600	560	1800	P7LP-804L
0.90	1812LS-123XJLB	1812LS-123XJLB	1812LS-103XJLB	12000	12000	10000	2200	200	5600	820	5600	6800	1800	P7LP-904L
1.0	1812CS-103XJLB	1812CS-103XJLB	1812CS-822XJLB	10000	10000	8200	1800	160	4700	680	4700	560	1500	P7LP-105L
1.3	1008CS-472XJLB	1008CS-472XJLB	1008CS-472XJLB	4700	4700	4700	1500	110	1800	620	1800	1800	1500	P7LP-135L
1.5	1008LS-682XJLB	1008LS-682XJLB	1008LS-562XJLB	6800	6800	5600	1200	100	3300	510	3300	360	1000	P7LP-155L
2.0	1008LS-332XJLB	1008LS-332XJLB	1008LS-332XJLB	3300	3300	3300	1200	100	3300	510	3300	360	1000	P7LP-205L
3.0	1008LS-332XJLB	1008LS-332XJLB	1008LS-272XJLB	3300	3300	2700	620	50	1500	300	1500	180	510	P7LP-305L
4.2	1008CS-182XJLB	1008CS-182XJLB	1008CS-182XJLB	1800	1800	1800	620	50	1200	300	1200	180	50	P7LP-425L
4.5	1008CS-152XJLB	1008CS-621XJLB	1008CS-821XJLB	1500	620	820	600	210	710	1200	560	800	250	P7LP-455L
5.0	1008CS-182XJLB	1008CS-222XJLB	1008CS-182XJLB	1800	2200	1800	390	30	910	130	910	110	300	P7LP-505L
6.0	1008CS-222XJLB	1008CS-272XJLB	1008CS-222XJLB	2200	2700	2200	240	200	620	90	560	75	220	P7LP-605L
9.0	1008CS-102XJLB	1008CS-102XJLB	1008CS-102XJLB	1000	1000	1000	220	3000	560	120	560	100	200	P7LP-905L
10	1008CS-102XJLB	1008CS-102XJLB	1008CS-102XJLB	1000	1000	1000	200	16	510	100	510	600	160	P7LP-106L
15	1008CS-681XJLB	1008CS-681XJLB	1008CS-561XJLB	680	680	560	130	10	330	75	300	36	100	P7LP-156L
17	1008CS-911XJLB	1008CS-911XJLB	1008CS-911XJLB	910	910	910	120	6	180	27	180	27	120	P7LP-176L
20	1008CS-561XJLB	1008CS-561XJLB	1008CS-471XJLB	560	560	470	100	10	270	39	270	3000	100	P7LP-206L
30	1008CS-331XJLB	1008CS-221XJLB	1008CS-221XJLB	330	220	220	100	15	140	75	120	56	70	P7LP-306L
45	1008CS-221XJLB	1008CS-181XJLB	1008CS-181XJLB	220	180	180	47	8.2	68	47	56	3000	3000	P7LP-456L
60	1008CS-151XJLB	1008CS-151XJLB	1008CS-121XJLB	150	150	120	30	2.7	68	24	600	9.1	27	P7LP-606L
70	1008CS-151XJLB	1008CS-151XJLB	1008LS-121XJLB	150	150	120	27	2.2	600	1000	600	7.5	200	P7LP-706L
88	1008CS-121XJLB	1008CS-121XJLB	1008CS-121XJLB	120	120	120	20	1.6	50	10	47	6.2	18	P7LP-886L
90	1008CS-121XJLB	1008CS-121XJLB	1008LS-101XJLB	120	120	100	20	1.6	50	10	47	6.2	18	P7LP-906L
100	1008CS-101XJLB	1008CS-101XJLB	1008CS-850XJLB	100	100	85	20	1.8	47	7.5	47	6	16	P7LP-107L
150	1008CS-620XJLB	1008CS-680XJLB	1008CS-500XJLB	62	68	50	100	1	30	4.7	30	3.3	10	P7LP-157L
200	1008CS-470XJLB	1008CS-470XJLB	1008CS-390XJLB	47	47	39	8.2	1	200	3	200	2.2	6.8	P7LP-207L
220	1008CS-330XJLB	1008CS-330XJLB	1008CS-330XJLB	33	33	33	8.2	1	200	3	200	2.2	6.8	P7LP-227L
250	1008CS-150XJLB	1008CS-120XJLB	1008CS-270XJLB	15	12	27	1.2	10	8.2	17	10	2.7	6	P7LP-257L
300	1008CS-270XJLB	1008CS-180XJLB	1008CS-180XJLB	27	18	18	8.2	1.5	10	7	9.5	5.1	5.6	P7LP-307L
400	1008CS-180XJLB	1008CS-120XJLB	1008CS-120XJLB	18	12	12	6.5	1	9.1	5.1	8.2	3.9	4.7	P7LP-407L
500	1008CS-100XJLB	0805CS-060XJLB	0805CS-060XJLB	10	6.8	6.8	4.7	1	5.6	6.2	4.3	4.3	3	P7LP-507L

Notes:

All values are for reference only. Layout and substrate affect final performance.

7th order elliptic filter (refer to schematics). Ref. 50 Ohms.

Use 0805 NPO/COG capacitors. Higher cut-off frequencies may require tighter tolerance.

Improved performance may be achieved by using other (typically larger) inductors. Use the RF Inductor Finder tool to find alternatives.