# Build Your LC Filter with Coilcraft Reference Designs

## 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 designs, including 3rd order Butterworth low-pass and high-pass, as well as 7th order elliptic. These designs 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 Designs

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.

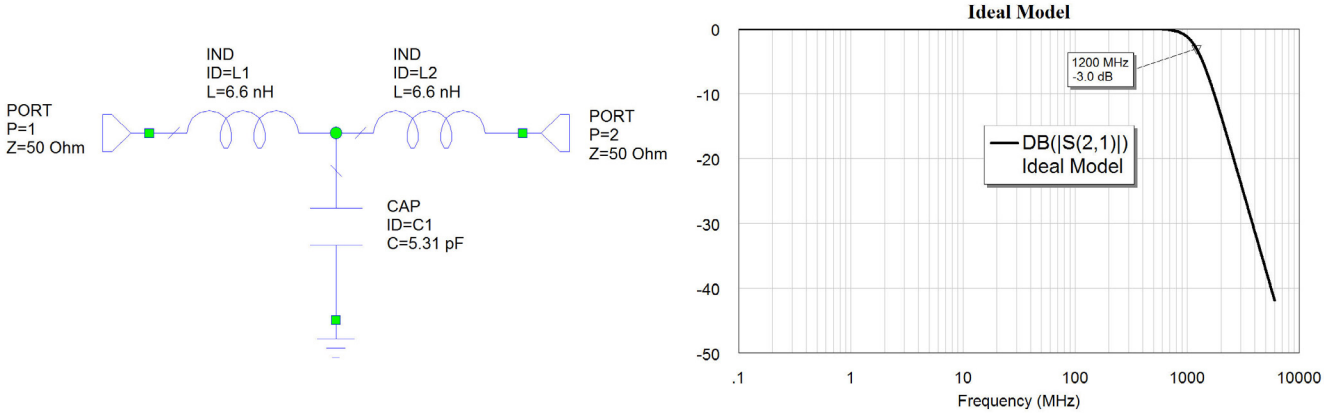
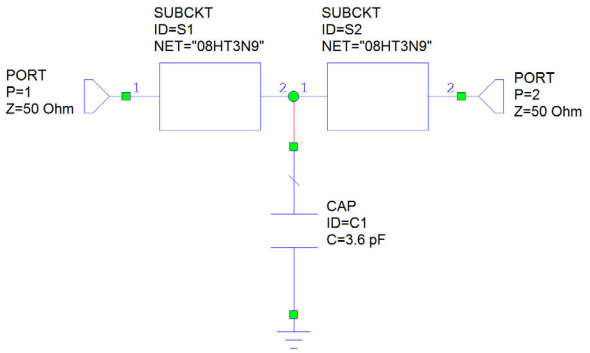



*Figure 1.*



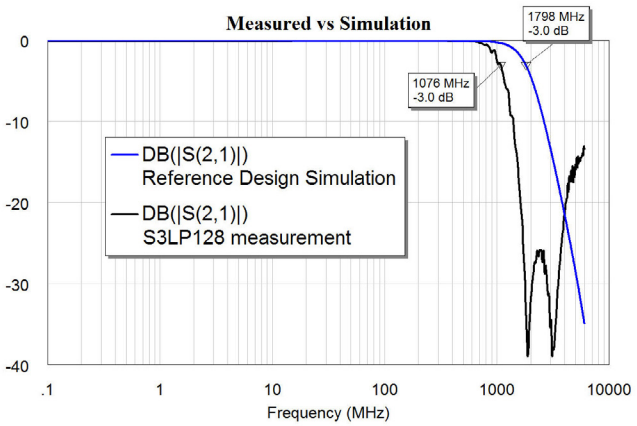




*Figure 2.*

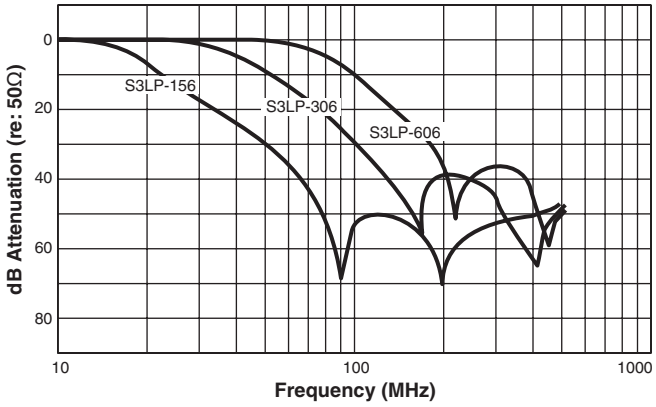
The inductors selected for 3rd order Butterworth reference designs are off-the-shelf Coilcraft 0805HT series. These wirewound ceramic chip inductors are low profile (only 0.035 inch high) and have a small footprint, offering tremendous board space saving. The 0805HT has tight tolerance at 2% to ensure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

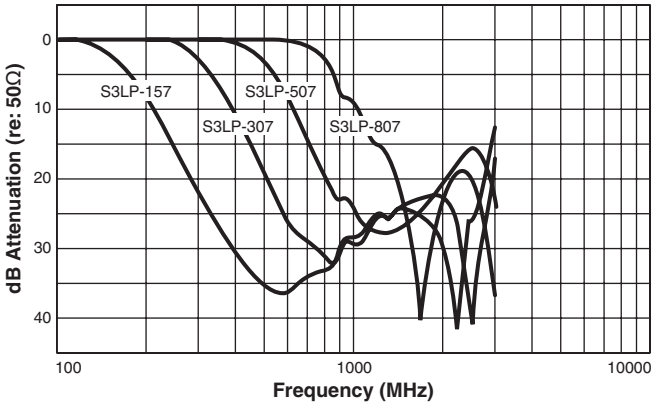
The 3rd order low-pass filters reference design provides a wide range of cut-off frequencies from 3 MHz to 3 GHz.

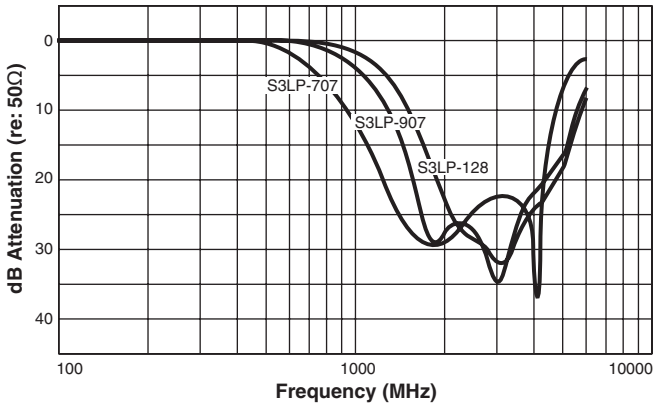
For 3-pole high-pass filter, 15 MHz to 900 MHz cutoff frequencies could be obtained. User may simply order the part number in the reference design BOM list to get the closest component values for the design requirements.

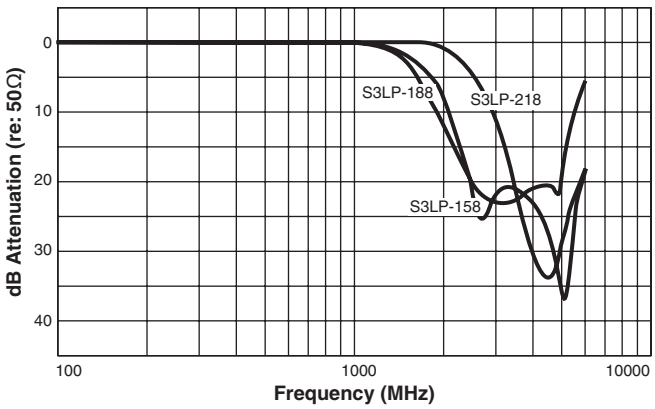
The designer may modify or enhance the filter design based on Coilcraft reference design (e.g., by using larger inductors to achieve improved performance). Coilcraft offers a wide range of off-the-shelf inductors that designers can choose from.

## Frequency Response – 3 Pole Low-Pass Filters*



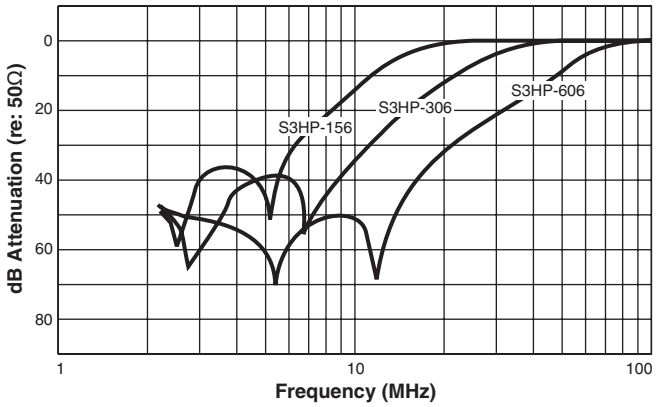



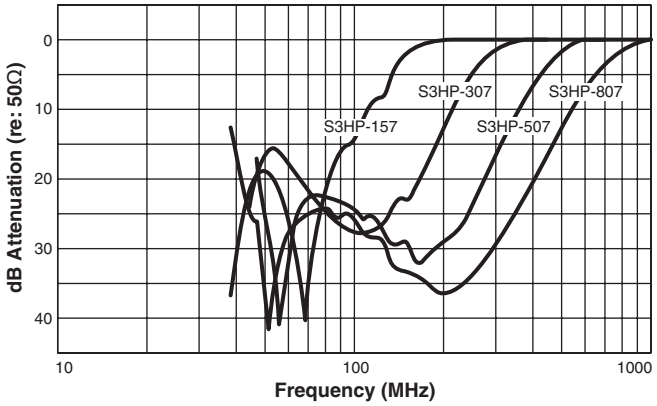




*Measured on Agilent/HP 8753D network analyzer (re: 50Ω)

# Frequency Response – 3 Pole High Pass Filters*




## Seventh Order Elliptic Filter Reference Design (page 5)

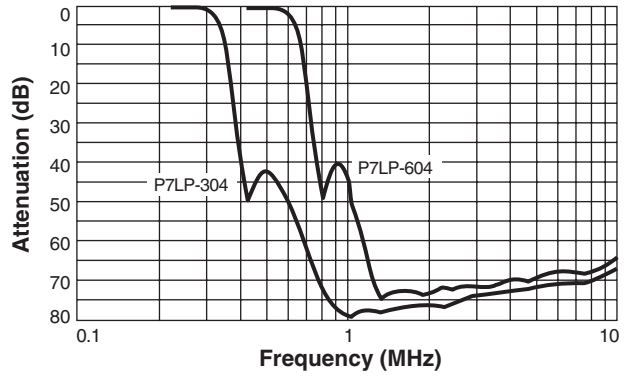
Compared to a Butterworth filter, elliptic filters have equalized ripple in both the passband and the stop-band. However, for the same order level, it has the fastest transition between passband and the stop-band. Coilcraft offers 7th order elliptic reference designs with less than 0.3 dB insertion loss 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.

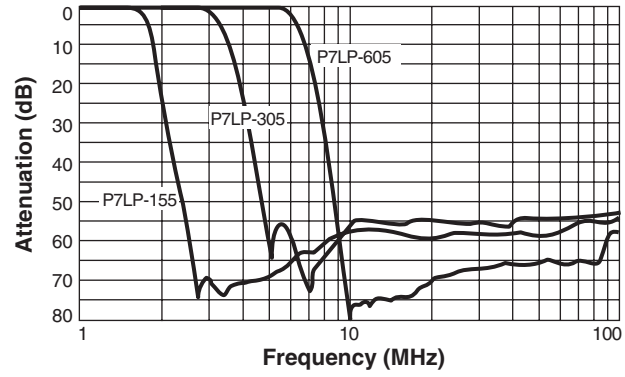
## Summary

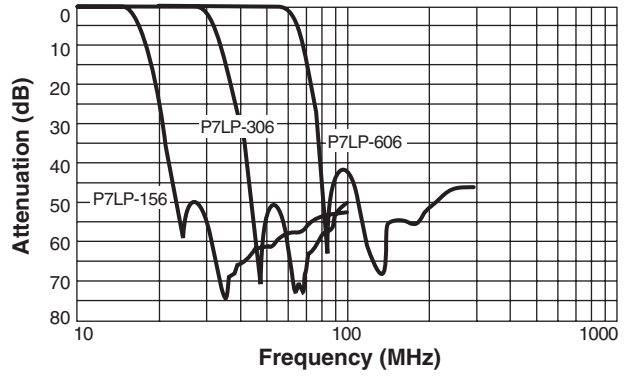
Typically, a passive LC filter design starts with calculations and then a very iterative trial-and-error process.

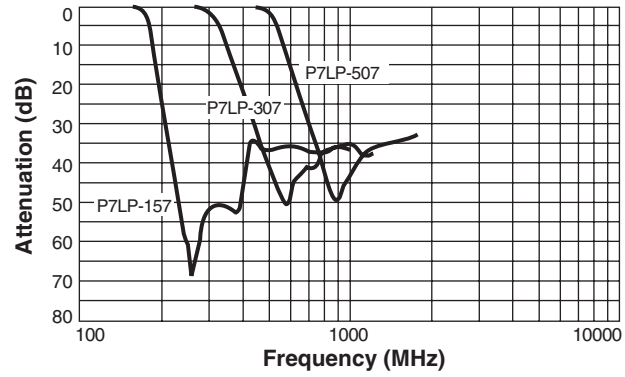
Coilcraft LC filter reference designs can save time, effort and cost for LC passive filter designers, allowing them to better select the right components and achieve desired performance. The reference designs included in this app note include BOMs of standard off-the-shelf inductors and capacitor values. 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)

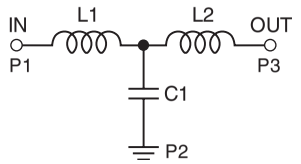
# LC Filter Circuit Designs

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

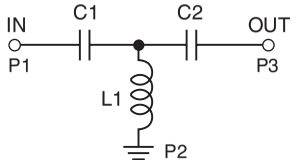
These low and high pass filter circuits serve a wide variety of filtering requirements. The design features 3rd order Butterworth alignment, 50 Ohm characteristic impedance and low insertion loss.

The S3LP and S3HP reference designs can incorporate the components into an overall 1812 size surface mount package.

**Low pass filter**




**High pass filter**




## 3-Pole Low Pass Filters

| Coilcraft design number | –3 dB cutoff (MHz) | L1 part number | L2 part number | L1 (nH) | L2 (nH) | C1 ±2% (pF) |
|---|---|---|---|---|---|---|
| S3LP305L | 3 | 0805HT-R79TGLB | 0805HT-R79TGLB | 790 ±2% | 790 ±2% | 2400 |
| S3LP605L | 6 | 0805HT-R79TGLB | 0805HT-R79TGLB | 790 ±2% | 790 ±2% | 1200 |
| S3LP106L | 10 | 0805HT-R63TGLB | 0805HT-R63TGLB | 630 ±2% | 630 ±2% | 680 |
| S3LP136L | 13 | 0805HT-R63TGLB | 0805HT-R63TGLB | 630 ±2% | 630 ±2% | 470 |
| S3LP156L | 15 | 0805HT-R50TGLB | 0805HT-R50TGLB | 500 ±2% | 500 ±2% | 390 |
| S3LP306L | 30 | 0805HT-R18TGLB | 0805HT-R18TGLB | 180 ±2% | 180 ±2% | 220 |
| S3LP456L | 45 | 0805HT-R18TGLB | 0805HT-R18TGLB | 180 ±2% | 180 ±2% | 120 |
| S3LP606L | 60 | 0805HT-R12TGLB | 0805HT-R12TGLB | 120 ±2% | 120 ±2% | 100 |
| S3LP706L | 70 | 0805HT-R10TGLB | 0805HT-R10TGLB | 100 ±2% | 100 ±2% | 91 |
| S3LP956L | 95 | 0805HT-72NTGLB | 0805HT-72NTGLB | 72 ±2% | 72 ±2% | 62 |
| S3LP107L | 100 | 0805HT-68NTGLB | 0805HT-68NTGLB | 68 ±2% | 68 ±2% | 56 |
| S3LP117L | 110 | 0805HT-68NTGLB | 0805HT-68NTGLB | 68 ±2% | 68 ±2% | 56 |
| S3LP157L | 150 | 0805HT-68NTGLB | 0805HT-68NTGLB | 68 ±2% | 68 ±2% | 33 |
| S3LP207L | 200 | 0805HT-33NTGLB | 0805HT-33NTGLB | 33 ±2% | 33 ±2% | 30 |
| S3LP237L | 230 | 0805HT-33NTGLB | 0805HT-33NTGLB | 33 ±2% | 33 ±2% | 24 |
| S3LP307L | 300 | 0805HT-33NTGLB | 0805HT-33NTGLB | 33 ±2% | 33 ±2% | 15 |
| S3LP357L | 350 | 0805HT-18NTGLB | 0805HT-18NTGLB | 18 ±2% | 18 ±2% | 15 |
| S3LP407L | 400 | 0805HT-17NTGLB | 0805HT-17NTGLB | 17 ±2% | 17 ±2% | 12 |
| S3LP457L | 450 | 0805HT-18NTGLB | 0805HT-18NTGLB | 18 ±2% | 18 ±2% | 10 |
| S3LP507L | 500 | 0805HT-18NTGLB | 0805HT-18NTGLB | 18 ±2% | 18 ±2% | 9.1 |
| S3LP707L | 700 | 0805HT-8N2TJLB | 0805HT-8N2TJLB | 8.2 ±5% | 8.2 ±5% | 6.8 |
| S3LP807L | 800 | 0805HT-8N2TJLB | 0805HT-8N2TJLB | 8.2 ±5% | 8.2 ±5% | 5.6 |
| S3LP907L | 900 | 0805HT-4N7TJLB | 0805HT-4N7TJLB | 4.7 ±5% | 4.7 ±5% | 5.6 |
| S3LP108L | 1000 | 0805HT-3N9TJLB | 0805HT-3N9TJLB | 3.9 ±5% | 3.9 ±5% | 4.7 |
| S3LP128L | 1200 | 0805HT-3N9TJLB | 0805HT-3N9TJLB | 3.9 ±5% | 3.9 ±5% | 3.6 |
| S3LP158L | 1500 | 0805HT-3N9TJLB | 0805HT-3N9TJLB | 3.9 ±5% | 3.9 ±5% | 2.7 |
| S3LP168L | 1600 | 0805HT-2N2TJLB | 0805HT-2N2TJLB | 2.2 ±5% | 1.8 ±5% | 2.7 |
| S3LP188L | 1800 | 0805HT-1N8TJLB | 0805HT-1N8TJLB | 1.8 ±5% | 1.8 ±5% | 2.0 |
| S3LP218L | 2000 | 0805HT-1N8TJLB | 0805HT-1N8TJLB | 1.8 ±5% | 1.8 ±5% | 1.5 |
| S3LP268L | 2600 | 0805HT-1N8TJLB | 0805HT-1N8TJLB | 1.8 ±5% | 1.8 ±5% | 1.0 |
| S3LP308L | 3000 | 0805HT-1N8TJLB | 0805HT-1N8TJLB | 1.8 ±5% | 1.8 ±5% | 0.5 |

## 3-Pole High Pass Filters

| Coilcraft design number | –3 dB cutoff (MHz) | L1 part number | L1 (nH) | C1 ±2% (pF) | C2 ±2% (pF) |
|---|---|---|---|---|---|
| S3HP156L | 15 | 0805HT-R22TGLB | 220 ±2% | 330 | 390 |
| S3HP306L | 30 | 0805HT-R18TGLB | 180 ±2% | 68 | 68 |
| S3HP606L | 60 | 0805HT-68NTGLB | 68 ±2% | 56 | 56 |
| S3HP107L | 100 | 0805HT-39NTGLB | 39 ±2% | 39 | 39 |
| S3HP157L | 150 | 0805HT-27NTGLB | 27 ±2% | 20 | 20 |
| S3HP307L | 300 | 0805HT-15NTGLB | 15 ±2% | 6.8 | 6.8 |
| S3HP507L | 500 | 0805HT-6N8TJLB | 6.8 ±5% | 5.6 | 5.6 |
| S3HP707L | 700 | 0805HT-3N9TJLB | 3.9 ±5% | 4.5 | 4.5 |
| S3HP807L | 800 | 0805HT-3N9TJLB | 3.9 ±5% | 3.0 | 3.0 |
| S3HP907L | 900 | 0805HT-3N9TJLB | 3.9 ±5% | 2.2 | 2.2 |

**Notes:**

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

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

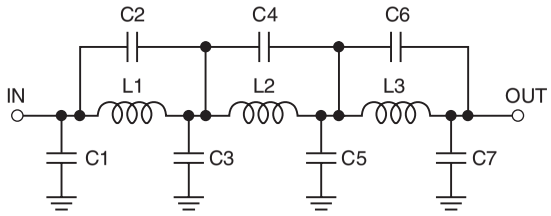
Improved performance may be achieved by using other (typically larger) inductors. Use the RF Inductor Finder tool to find alternatives.

# LC Filter Circuit Designs

## 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 reference designs incorporate the components shown in the table below.




## 7-Pole Low Pass Filters

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

**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.