Unit 17 Filter classification

In general, most filters can be specified by selecting one property or characteristic from each of the following groups:

- Active or passive
- High pass, low pass, band pass, band stop
- First, second, third ... order
- Smoothness of response (phase or amplitude).

Active and passive filters. So far we have only looked at passive filters which are filters constructed from passive components such as resistors, capacitors and inductors. In Unit 48 we will look at active filters which use transistors or operational amplifiers and usually have some gain.

High pass filters are characterized by the fact that they pass signals at high frequencies and attenuate or block signals at low frequencies.

Low pass filters are characterized by passing direct voltages and low frequencies and tend to attenuate high frequency signals. In general, they have a resistive connection between input and output.

Band pass filters pass signals at frequencies within a specified pass band and tend to block signals at frequencies above and below this pass band. They are usually specified as having a centre frequency and a 3 dB bandwidth or frequency range within which the response is within 3 dB of the response at the centre frequency. The Q factor of a filter is defined by:

$$Q = \frac{\text{Centre frequency}}{\text{Pass band}} = \frac{f}{B}$$

High Q factors are associated with sharp peaks in the frequency response which would be characteristic of a radio receiver selecting one signal frequency out of the many in the radio spectrum. There is a price to be paid for high Q factor or high selectivity and it is that the stability is reduced and the filter centre frequency tends to drift. As a general rule, passive band pass filters will usually contain both inductors and capacitors in the circuit.

Band stop filters block signals in a specified range or more accurately they attenuate the signals by some minimum amount usually specified in dB.

These band stop filters can be constructed from resonant LCs as shown in Figure 17.1. There is also another type of band stop filter which uses a low pass filter and a high pass filter operating in parallel. The band stop is then associated with the region between the two nonoverlapping filters where both responses attenuate the signal.

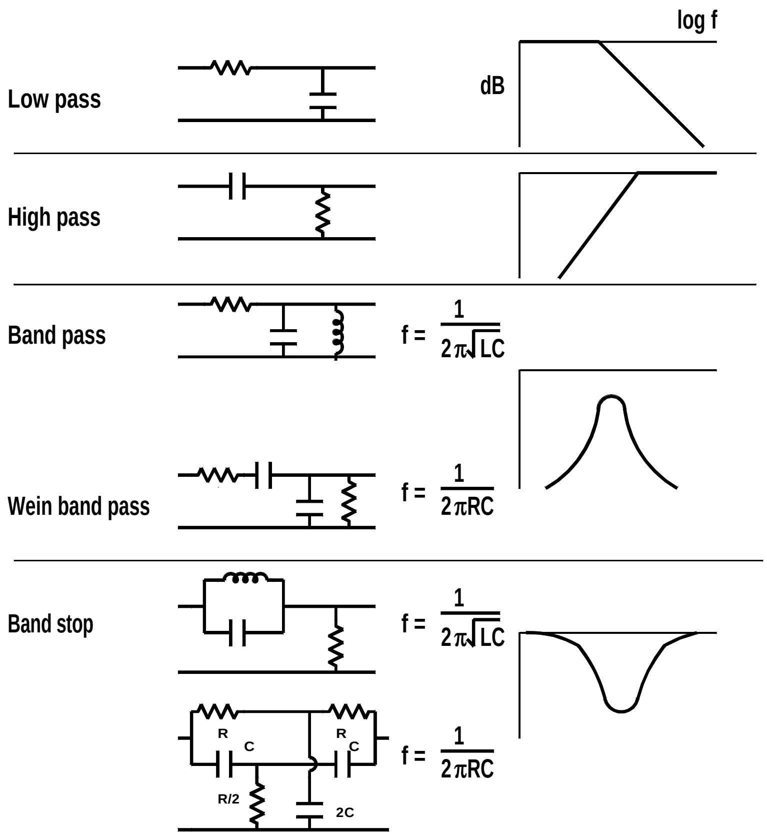

Figure 17.1: Typical filter circuits and response curves.

Filter order is most easily specified as the number of simple RC or RL filters which are combined in the composite filter. The order of the filter has its greatest effect on the slope of the shoulders of the filter response. If N is the order of the filter, then the total slope of the shoulder is $N \times 20\,\text{dB}$ per decade. The total slope means that two CR high pass filters in series will give a fall-off of the response curve of 40 dB per decade of frequency. However, a CR high pass and RC low pass filter, when combined to give a band pass Wein filter, have a 20 dB per decade fall-off on the low side and another 20 dB per decade fall-off on the high side to give a total distributed fall-off of 40 dB per decade.

Smoothness of response describes the permissible ripple or variation in the amplitude or phase shift of the signal within the filter pass band. It is usually specified by requiring the filter to be a Butterworth, Chebyshev, Bessel or some other specific design.

17.1 Example

17.1 Select a circuit and calculate suitable component values for a band pass filter having a centre frequency of 11 kHz.

From Figure 17.1, we can select a suitable LC filter circuit, as shown in Figure 17.2. The R_2 is included to denote the resistance of the inductor but we will ignore R_2 in our calculations since it is usually very small.

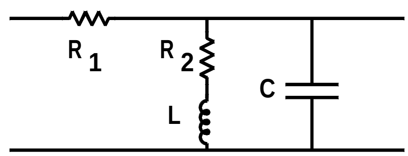

Figure 17.2: Circuit for band pass filter.

The readily available off the shelf component values for inductances are restricted in range so we will select the inductor first. Take a value of 1 mH as a reasonable first guess. Then:

$$\begin{aligned}
\text{Using} \quad f_r &= \frac{1}{2\pi\sqrt{LC}} \\
\text{we get} \quad C &= \frac{1}{4\pi^2 f_r^2 L} \\
&= \frac{1}{4 \times 9.87 \times 1.21 \times 10^8 \times 1 \times 10^{-3}} \\
&= \frac{1}{4.777 \times 10^6} \\
&= 0.21 \times 10^{-6}\,\mathrm{F} = 0.21\,\mu\mathrm{F}
\end{aligned}$$

17.2 Problems

17.1 Figure 17.3 shows a circuit for a band stop or notch filter. It is composed of a high pass filter in parallel with a low pass filter. Identify and sketch the low pass part of the filter. Identify and sketch the high pass part of the filter.

Plot the frequency response of each of these two component filters on the same sheet and construct the composite response. Plot the phase response of each of the component filters and construct the composite phase response.

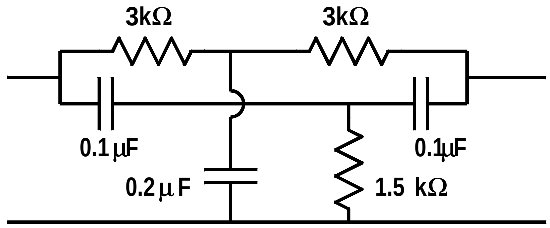

Figure 17.3: Problem 17.1.

17.2 An oscilloscope is switched into XY mode and the input signal to a filter is fed to the X deflection oscilloscope input and the filter output is fed to the Y deflection oscilloscope input as shown in Figure 17.4. After suitable adjustment of the oscilloscope sensitivity, an ellipse is obtained on the screen as shown in Figure 17.4.

A is the separation of the two points where the ellipse intercepts the Y axis and B is the vertical separation of the maximum and minimum Y displacements. Show that $\sin\phi = \frac{A}{B}$.

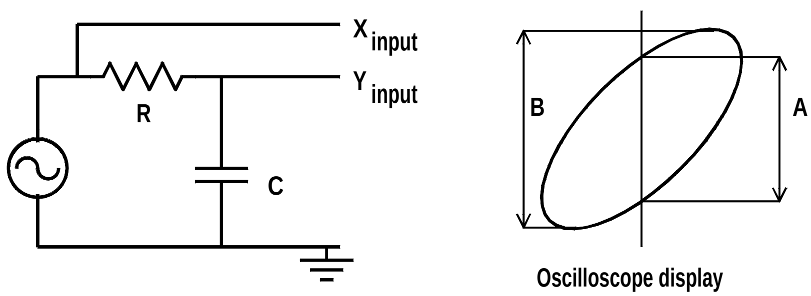

Figure 17.4: Problem 17.2.

17.3 Design a high pass filter having a corner frequency of 2.5 kHz and construct the Bode plot for the filter.

17.4 The RCL band stop filter shown in Figure 17.5 can be considered as an RC low pass filter at low frequencies and as an RL high pass filter at high frequencies. Show that the phase response of the filter is of the form shown in the diagram in Figure 17.5. Indicate the shape of the ellipse which you would expect to obtain for frequencies in each section of the phase response curve when the phase display circuit of Problem 17.2 is used.

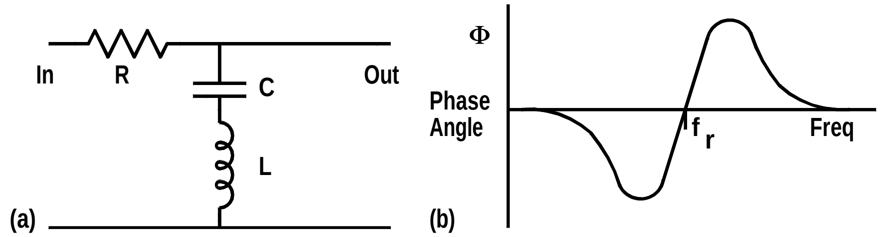

Figure 17.5: Problem 17.4.

17.5 Design a band pass filter for a centre frequency of 7.5 kHz and sketch the response.

17.6 Design a Wein filter for a centre pass frequency of 3.3 kHz.

17.7 If the component values for the circuit in Figure 17.2 are $R_1 = 1\,\mathrm{k}\Omega$, $R_2 = 0\,\Omega$, $L = 20\,\mathrm{mH}$ and $C = 0.5\,\mu\mathrm{F}$, calculate the band pass centre frequency.