Chapter 3

Passive Filter and Frequency Content of Waveforms

3.1 Introduction

Ever since contemporary humans knew how to use electronic components, passive filters have been around. Then what else, if any, can be learned? Well, the quartic equation

\[ x^4 + a_1 \cdot x^3 + a_2 \cdot x^2 + a_3 \cdot x + a_4 = 0 \]

has been around for at least several hundred years, and it still defies a solution. Does it mean a two-section filter (Fig. 3-1) cannot be designed since the characteristic function is of the fourth degree? The answer is yes and no. Yes, it can be designed; but no, it cannot be designed optimally. Depending on what purpose it is asked to serve, the requirement perhaps can be optimized at the expense of others. In other words, a compromise is in order. A subsequent question to ask is: On what basis can such a compromise be reached? The answer lies in recognizing the fact that switching waveforms generated by circuits presented in the previous chapter are very rich in harmonic content. This chapter briefly examines the effects harmonic components imposed upon passive filters.

![Figure 3-1 Two-section LC filter](image-url)
3.2 Filter Development and Characterization

In Chapter 1, the capacitor is said to possess the property of slowing voltage change. It is therefore very tempting to guess that a capacitor alone was the first filter configuration selected (Fig. 3-2a). But a capacitor in solo simply cannot handle DC current well. Out comes the series inductor to the rescue (Fig. 3-2b). Naturally it is entirely logical to expect an extension by combining both the inductor and the capacitor. The combination (Fig. 3-2c), a single-section LC without any dissipative parasitic resistance, was known to exhibit oscillatory properties. So an external resistance was added to yield controlled damping. By this latter act the stage was set for fanning out more sophisticated combinations including single T, single π, double T, simple cascading, and so on.

![figure 3-2 genesis of single-section LC filter](image)

Needless to say, there are numerous ways of evaluating or specifying a circuit block. Typically, the input impedance, the output impedance, and the transfer function lead the list. However, it was also discussed in Chapter 2 that impedance interactions can drastically alter circuit functions. Normally the word interaction emphasizes the interrelation of at least two parties. Would it imply that the standalone properties of a filter do not mean much? Besides the philosophical fact that everything is relative, electronic circuit behavior must be judged on "the same wavelength," as the old saying goes, but in a different context. For instance, the output impedance of the filter in Fig. 3-3a can be easily shown to follow the profile of Fig. 3-3b. To have technical significance, however, the output impedance magnitude must be viewed in comparative terms against something else in the same frequency range. The most logical yardstick for magnitude comparison is of course the load input impedance. And, once this process is introduced, complexities and possibilities just explode, since the relative magnitude of the source filter output impedance and the load input impedance can take unlimited forms (Fig. 3-3c–h). These