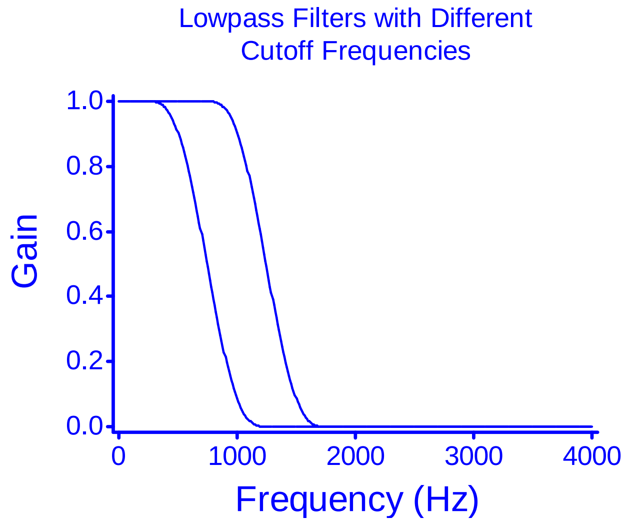
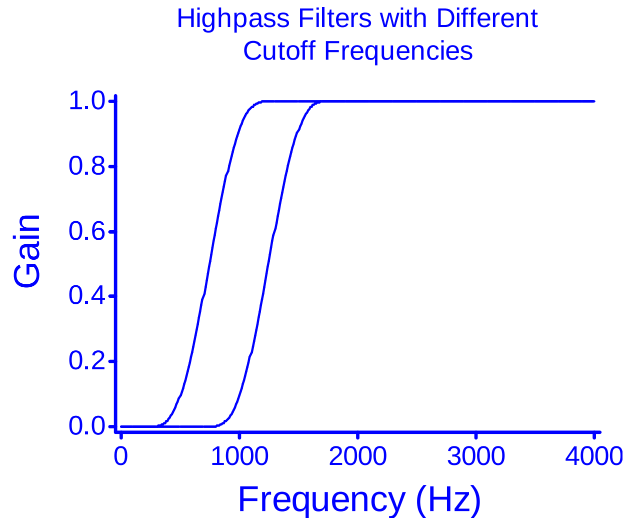
Background

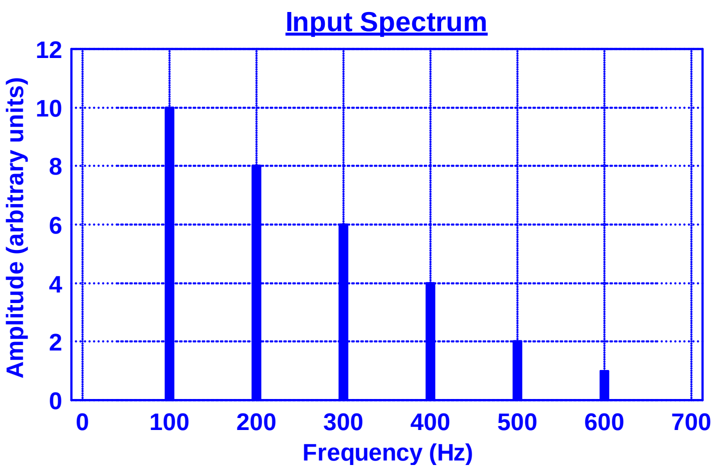
Acoustical filters are systems that are ***frequency selective***, which simply means that they provide different amounts of *amplification* or *gain* at different frequencies. A frequency response curve (FRC) is a graph that shows the amount of amplification provided by the filter at each frequency. The term *gain* is a synonym for amplification; i.e., *amplification* and *gain* are completely interchangeable. The figure at the left shows two frequency response curves for *lowpass* filters; that is, these FRCs have relatively high gain at low frequencies and lower gain at higher frequencies (hence the term *lowpass* filter – these filters allow mainly low frequencies to pass through). These two lowpass FRCs differ in *cutoff frequency*, the frequency at which gain makes the transition from high amplification to lower amplification. (Cutoff frequency has a very specific arithmetic definition, but we do not need to be concerned about how it is calculated.) The two FRCs on the right describe *highpass* filters – filters that provide high amplification at higher frequencies while attenuating (weakening) lower frequency components.

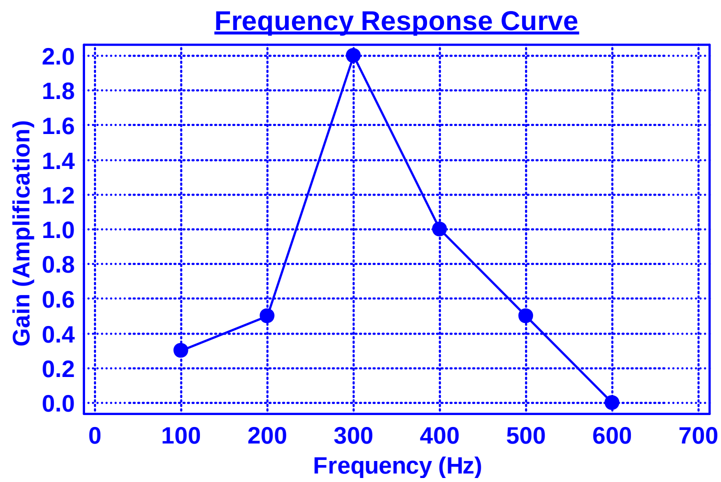




Gain or amplification *factors* are just that – an amplification factor is a *multiplier*. For example, suppose that an FRC indicates that the gain of a filter is 2.0 at 500 Hz, and assume that the *spectrum* of a signal that is put into that filter (the *input spectrum*) shows that the signal has an amplitude of 10 at that same frequency of 500 Hz (don't worry about what the amplitude units are; for now it's just 10). So, at 500 Hz the input amplitude is 10 and the amplification factor is 2.0. When you look at the *output spectrum* (the spectrum of the signal measured at the *output* of the filter), what will the amplitude be at 500 Hz? All you need to do is multiply the input amplitude at 500 Hz (10) by the amplification factor at 500 Hz (2.0): 10 x 2.0 = 20.

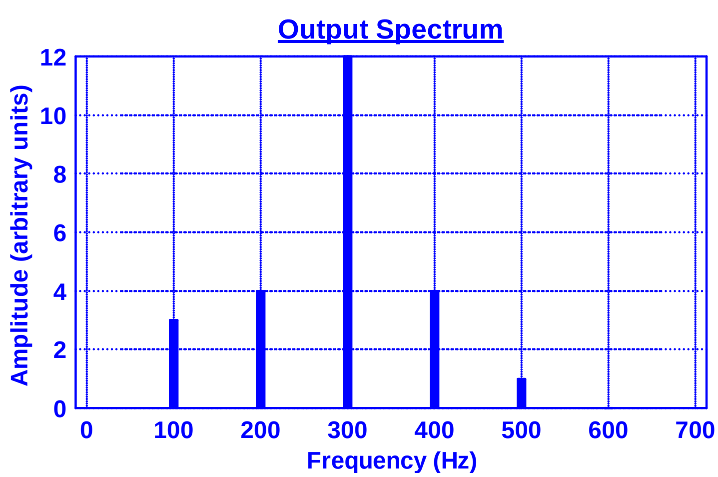
Ok, so that little arithmetic allows you to figure out what the output amplitude would be for one frequency component of an input signal (500 Hz for that example) when you know the gain of the filter at that frequency. Figuring out what the complete output spectrum would look like at all frequencies is just a matter of repeating this arithmetic for each frequency.



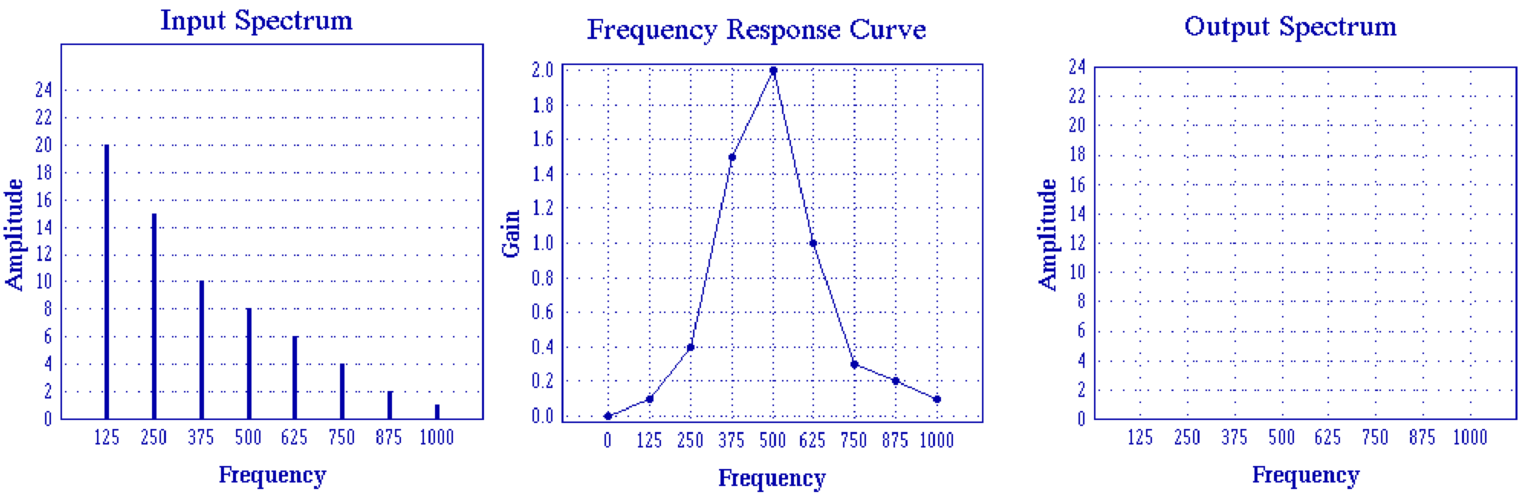


Shown at the left in the figure above is the *input spectrum* of a signal that serves as the input to a filter whose FRC is shown at the right. The table below shows the input spectrum in the form of an *array* or *vector*. The numbers in each of the cells of the array hold the amplitudes at each frequency – 10 at 100 Hz, 8 at 200 Hz, 6 at 300 Hz, etc. There is a second array representing the FRC. This is the same kind of array representation, but in this case the numbers in each cell are *amplification factors* or *gains* for the same set of frequencies – 0.3 at 100 Hz, 0.5 at 200 Hz, etc. To find out what the output spectrum looks like you just multiply the input amplitude at 100 Hz by the gain of the filter at 100 Hz (10 x 0.3 = 3), then you multiply the input amplitude at 200 Hz by the gain of the filter at 200 Hz (8 x 0.5 = 4), then you multiply the input amplitude at 300 Hz by the gain of the filter at 300 Hz (6 x 2.0 = 12), etc., until you have done this for each frequency. This process is called *array multiplication* or *vector multiplication*. The set of numbers in the last row indicate what the *output spectrum* would look like when a signal with the spectrum in the top left figure serves as the input to a filter with the FRC that is shown in the top right figure. The figure at the bottom shows what the output spectrum would look like graphically. Sample FRC problems are given on page 3; the solutions are on page 4.

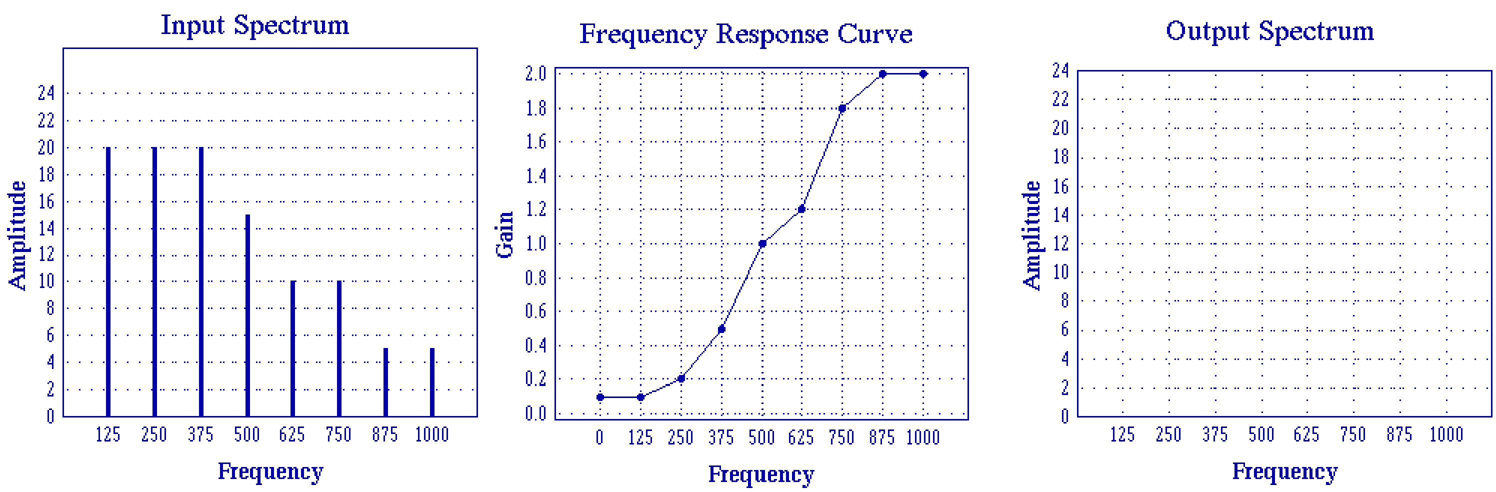
Frequency	**100**	**200**	**300**	**400**	**500**	**600**	**700**
Input Spec	**10**	**8**	**6**	**4**	**2**	**1**	**0**
FRC Gain	**0.3**	**0.5**	**2.0**	**1.0**	**0.5**	**0.0**	**0.0**
Output Spec	**3.0**	**4.0**	**12.0**	**4.0**	**1.0**	**0.0**	**0.0**



Frequency Response Problems



Assume that a signal with the amplitude spectrum show at the left is modified by a filter with the frequency response curve show in the middle. Show what the output spectrum would look like.



Answers to Frequency Response Problems