ECE 215 Spring 2025

Objective 2.2:

Ideal Filters

UNITED STATES
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ACADEMY

Objective 2.2

I can identify types of ideal filters, determine their cutoff frequencies, and analyze their output given an input sinusoidal signal or signal spectrum.

DEFINITIONS

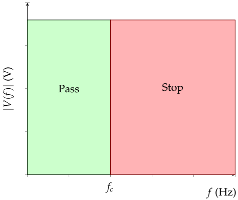
- **Bandwidth**: How much frequency space (range) a signal occupies.

$$BW = f_{max} - f_{min}$$

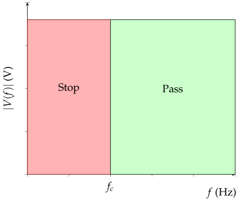
- **Electronic filter**: A circuit that, based on frequency, selectively scales and shifts the sinusoidal components in a signal
- **Passband**: Range of frequencies not significantly attenuated
- **Stopband**: range of frequencies significantly attenuated
- **Cutoff frequency**: Frequency at which the filter transitions from/to passband to/from stopband
- **Ideal filter**: Scales all passband amplitudes by 1; scales all stopband amplitudes by 0; abruptly transitions from passband to stopband at cutoff frequency(ies); introduces no phase shift

Filter Types

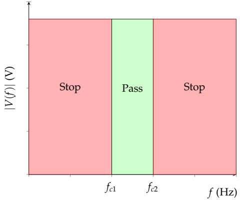
LPF: pass all frequencies below f_c



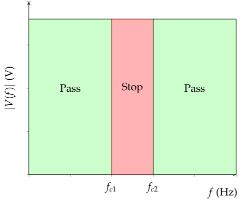
HPF: pass all frequencies above f_c



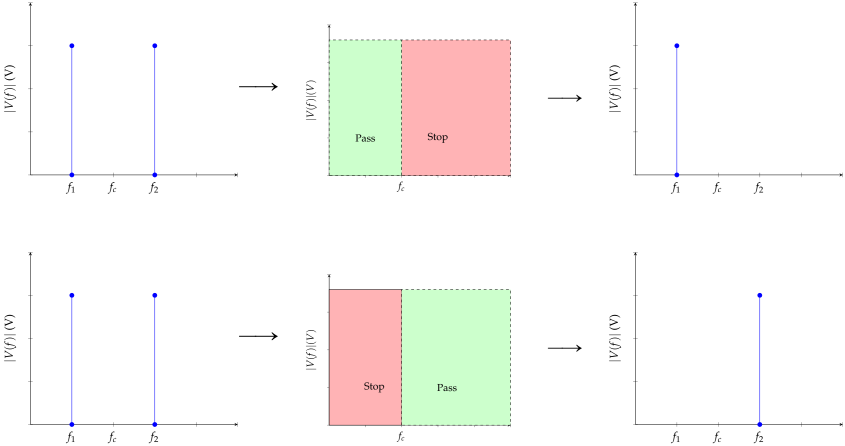
BPF: pass all frequencies between $f_{c1} < f < f_{c2}$



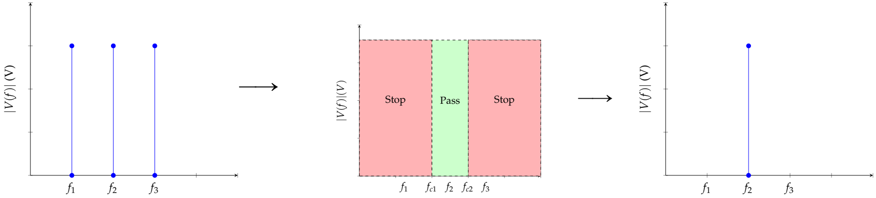
BSF: reject all frequencies between $f_{c1} < f < f_{c2}$; also known as band reject filter

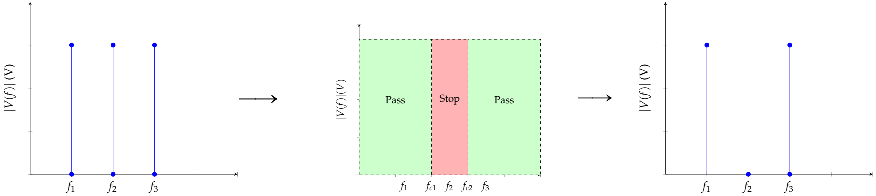


LPF and HPF in Action



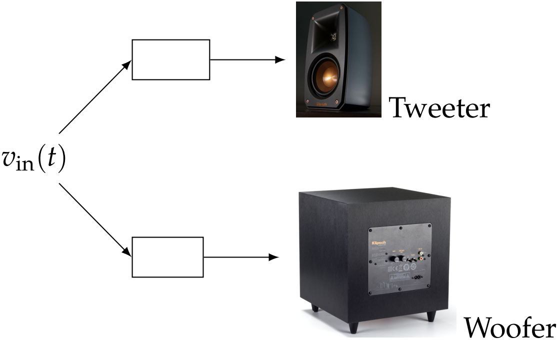
Band Pass and Band Stop in Action





Example: HPF and LPF

Draw the block diagram for a filter system to allow only signals with a frequency above 1.5kHz to be sent to the tweeters and lower frequency signals to be sent to the woofers.



Example: BPF

A signal passes, $v(t)$, through a band pass filter with $f_{c1} = 3$kHz and $f_{c2} = 9$kHz - what is the output?

$$\begin{aligned} v(t) = {} & 100\cos 360^\circ * 2k * t + 62\cos 360^\circ * 4k * t \\ & + 81\cos 360^\circ * 6k * t + 71\cos 360^\circ * 8k * t \\ & + 86\cos 360^\circ * 10k * t \end{aligned}$$

What if the signal is right at f_c?

Example: BSF

Determine $v_{out}(t)$, for

$$v_{in} = 8 + 3\cos 360^\circ * 4k * t + 4\cos 360^\circ * 6k * t + 5\cos 360^\circ * 8k * t$$

$$v_{\text{in}}(t) \longrightarrow \boxed{\begin{array}{c}\text{BSF}\\ f_{c1} = 500\text{ Hz}\\ f_{c2} = 3\text{ kHz}\end{array}} \longrightarrow v_{\text{out}}(t) =$$

Example: Cutoff Frequency

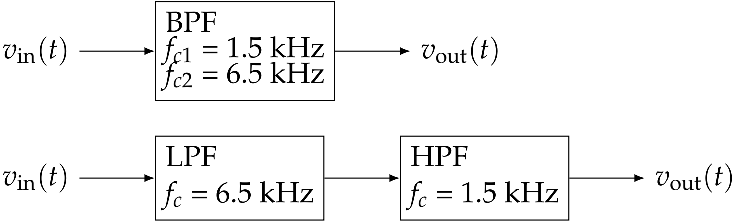
Find the cutoff frequency for the Filter. What type of filter is it?

$$
\begin{aligned}
v(t) = 8 &+ 3\cos 360^\circ * 4k * t + 4\cos 360^\circ * 6k * t \\
&+ 5\cos 360^\circ * 8k * t
\end{aligned}
$$

$$
\boxed{v_{\text{in}}(t)} \longrightarrow \boxed{\text{Filter}} \longrightarrow \boxed{v_{\text{out}}(t) = 8 + 3\cos 360^\circ * 4k * t}
$$

Example: Combining Filters

True or false: These two systems perform the same function.



Practice

Determine and plot $v_{out}(t)$ for the following filters

- LPF ($f_c = 4$kHz)
- HPF ($f_c = 5$kHz)
- BPF ($f_{c1} = 3$kHz and $f_{c2} = 8$kHz)
- BSF ($f_{c1} = 3$kHz and $f_{c2} = 6$kHz)

given

$$v_{in}(t) = 6 + 10\cos 360^\circ * 1k * t + 8\cos 360^\circ * 2k * t + 7\cos 360^\circ * 4k * t + 5\cos 360^\circ * 8k * t + \cos 360^\circ * 10k * t$$