# Passive Filters

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>low pass</td>
<td>pass low frequencies</td>
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<tr>
<td>high pass</td>
<td>pass high frequencies</td>
</tr>
<tr>
<td>band pass</td>
<td>pass a band of frequencies</td>
</tr>
<tr>
<td>band stop</td>
<td>reject a band of frequencies</td>
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<tr>
<td>notch</td>
<td>reject a specific frequency</td>
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</table>
Passive low-pass filter

\[ f_c = \frac{1}{2\pi RC} \]

\[ f_c = \frac{1}{2\pi L/R} \]

Low-frequency passes through

High-frequency is attenuated

70.7% response at the cutoff frequency

First-order response rolls off at 20dB per decade
Passive high-pass filter

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\[ f_c = \frac{1}{2\pi L/R} \]

High-frequency passes through

Low-frequency is attenuated

70.7% response at the cutoff frequency

First-order response climbs at 20dB per decade
Cascading passive filters

The response should roll off at \( n \times 20 \text{dB} \) per decade, but...
Passive band-pass filter

cascaded high and low pass
passes signals between the two corner frequencies
“Twin T” passive notch filter

Targeted attenuation of a single frequency

For 60 Hertz, R~2.7k, C~1uF

\[ f_c = \frac{1}{2\pi RC} \]
Active Filters

use op-amps to:

perform simultaneous amplification

perform simultaneous buffering

get full RLC effects without the need for inductors
Active low-pass filter

\[
f_c = \frac{1}{2\pi R_2 C}
\]
Sallen-Key active low-pass filter

second-order low pass
attenuates at 40 dB / decade above cutoff
adjustable sharpness (Q)

\[ f_c = \frac{1}{2\pi \sqrt{R_1 C_1 R_2 C_2}} \]

\[ Q = \frac{\sqrt{R_1 C_1 R_2 C_2}}{C_2 (R_1 + R_2)} \]

maximum flatness at \( Q = 0.707 \) (“butterworth”)
Sallen-Key active high-pass filter

\[ f_c = \frac{1}{2\pi \sqrt{R_1 C_1 R_2 C_2}} \]

\[ Q = \frac{\sqrt{R_1 C_1 R_2 C_2}}{C_2 (R_1 + R_2)} \]

second-order high pass
attenuates at 40 dB / decade before cutoff
adjustable sharpness (Q)

maximum flatness at Q = 0.707 (“butterworth”)
active “Twin-T” notch filter

\[ f_c = \frac{1}{2\pi RC} \]

introduce feedback
adjustable Q (sharpness)

Bode Diagram
Digital Filters

![Graph showing velocity over time for digital filters](image-url)
Infinite horizon (first-order low-pass) filter

\[ \hat{v}_i = \beta \hat{v}_{i-1} + (1 - \beta) v_i \]

 Equivalent analog bandwidth (rad/sec)

\[ f = \frac{1}{\tau} = \frac{1 - \beta}{\beta \Delta t} \]
#define BETA 0.92

... float angle=0;
... while(1){
   ... angle = BETA*angle + (1-BETA)*ADC;
   ... }