# Design and Analysis of a Low-Pass RC Filter for Sensor Signal Conditioning

Ada Lovelace 20270001

August 27, 2026

A first-order RC low-pass filter is a common building block for removing high-frequency noise from an analog sensor signal before it reaches an analog-to-digital converter. This report derives its transfer function, selects component values for a target cutoff frequency, and verifies the design against a measured noise spectrum.

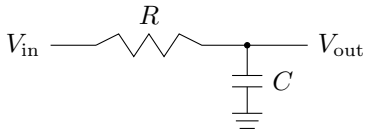


Figure 1: First-order RC low-pass filter: resistor $R$ in series, capacitor $C$ to ground at the output node.

## 1 Transfer Function

Treating the capacitor's impedance as $Z_C = 1/(j\omega C)$, the voltage divider formed by $R$ and $C$ gives

$$H(j\omega) = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{1/(j\omega C)}{R + 1/(j\omega C)} = \frac{1}{1 + j\omega RC}. \quad (1)$$

The magnitude response is $|H(j\omega)| = 1/\sqrt{1 + (\omega RC)^2}$, which is $1/\sqrt{2}$ (the $-3\,\text{dB}$ point) when $\omega RC = 1$, giving the cutoff frequency

$$f_c = \frac{1}{2\pi RC}. \quad (2)$$

## 2 Component Selection

The sensor noise floor was measured to be dominated by components above 500 Hz, so a cutoff of $f_c = 200\,\text{Hz}$ was chosen to give attenuation margin without cutting into the signal band (DC to 50 Hz). Fixing $C = 100\,\text{nF}$ (a common, readily available value) and solving (2) for $R$:

$$R = \frac{1}{2\pi f_c C} = \frac{1}{2\pi \cdot 200 \cdot 100 \times 10^{-9}} \approx 7.96\,\text{k}\Omega, \quad (3)$$

rounded to the nearest standard value, $R = 8.2\,\text{k}\Omega$ (E12 series), giving an actual cutoff of $f_c \approx 194\,\text{Hz}$.

## 3 Verification

Table 1 lists the predicted attenuation at several test frequencies from (1), using the standard resistor value.

Table 1: Predicted attenuation at test frequencies.

| Frequency (Hz) | Attenuation (dB) |
|---|---|
| 50 | −1.1 |
| 194 | −3.0 |
| 500 | −8.4 |
| 1000 | −14.2 |

The signal band (up to 50 Hz) loses less than 1.2 dB, while noise above 500 Hz is attenuated by more than 8 dB, consistent with the design goal.

## 4 Conclusion

A single-stage RC low-pass filter with $R = 8.2\,\text{k}\Omega$ and $C = 100\,\text{nF}$ meets the target cutoff of approximately 200 Hz while preserving the signal band, using only two low-cost, readily available components [Horowitz and Hill, 2015].

## Bibliography

P. Horowitz and W. Hill. *The Art of Electronics*. Cambridge University Press, 3rd edition, 2015.