$7V \rightarrow 10V$ Gain Stage Transfer Functions

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1 Inverting Operational Amplifier

Figure 1 shows an inverting operational amplifier circuit with feedback impedance Z_F comprising resistor R_F in parallel with capacitor C. The feedback impedance is

$$
\begin{aligned}
Z_F &= \frac{1}{sC + \frac{1}{R_F}} \\
&= \frac{R_F}{1 + sCR_F}
\end{aligned}
\tag{1}
$$

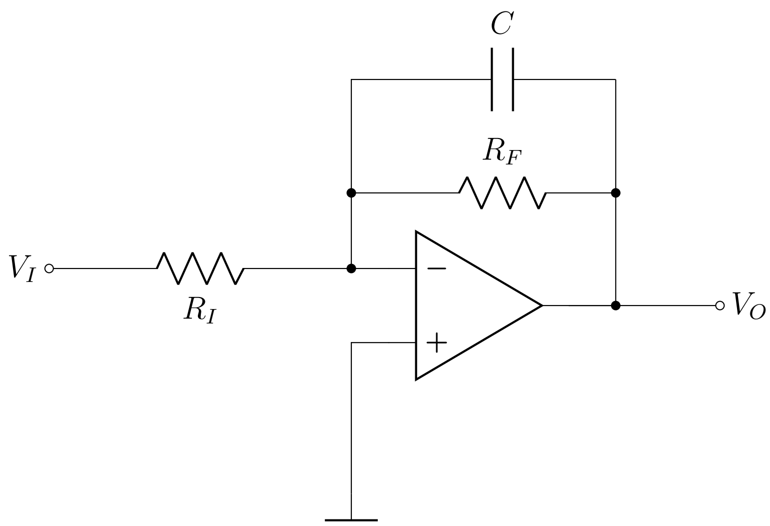

Figure 1: Inverting Low Pass Filter

The transfer function is given by

$$G(s) = -\frac{Z_F}{R_I}$$
$$= -\frac{R_F}{R_I} \times \frac{1}{1 + sCR_F}$$

Applying $s = j\omega$, and $\omega = 2\pi f$, the transfer function has a single pole representing the well-known low pass filter. The gain is $-\frac{R_F}{R_I}$, and the -3dB cutoff frequency is at $f_c = \frac{1}{2\pi CR_F}$ after which the response drops off at -20dB/decade.

2 Non-Inverting Operational Amplifier

The circuit of Figure 2 applies a similar idea to that above by incorporating a feedback capacitor in the non-inverting operational amplifier circuit.

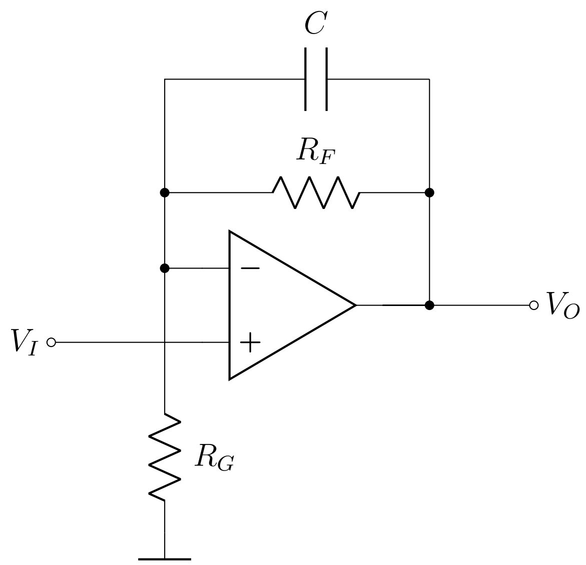

Figure 2: Noninverting Amplifier

As before, the feedback impedance is given by Equation 1. The new transfer function for the non-inverting configuration is

$$G(s) = 1 + \frac{Z_F}{R_G}$$
$$= \frac{R_G + Z_F}{R_G}$$

$$
\begin{aligned}
&= \frac{R_G + \frac{R_F}{1+sCR_F}}{R_G} \\
&= \frac{R_G(1+sCR_F) + R_F}{R_G(1+sCR_F)} \\
&= \frac{R_F + R_G + sCR_F R_G}{R_G(1+sCR_F)} \\
&= \frac{R_F + R_G}{R_G} \times \frac{1 + sC\frac{R_F R_G}{R_F+R_G}}{1+sCR_F}
\end{aligned}
$$

Once again, by applying $s = j\omega$, and $\omega = 2\pi f$, we evaluate the transfer function. The gain is $1 + \frac{R_F}{R_G}$, but now there is a zero and pole respectively at

$$
\begin{aligned}
f_z &= \frac{1}{2\pi C\frac{R_F R_G}{R_F+R_G}} \\
f_p &= \frac{1}{2\pi C R_F}
\end{aligned}
$$

For the desirable $7V \rightarrow 10V$ gain, the pole and zero effectively cancel each other. Some practical values will suffice to demonstrate : $C = 10\text{nF}$, $R_F = 35.11k$, and $R_G = 75k$ give $f_p = 453.3\text{Hz}$, and $f_z = 665.5\text{Hz}$. Given the pole and zero are so close, they effectively cancel.

3 Conclusion

For practical circuit component values in the $7V \rightarrow 10V$ non-inverting operational amplifier circuit, the capacitor C is redundant. The circuit does not operate as a low pass filter.