An Approximation of the Op-Amp Transfer Function

Recall the complex transfer function describing the **differential** gain of an op-amp is:

$$A_{op}(\omega) = \frac{v_{out}(\omega)}{v_d(\omega)} = \frac{A_0}{1 + j\left(\omega/\omega_b\right)}$$

For frequencies **much less** than the break frequency, we find that $\omega/\omega_b \ll 1$ and thus this gain is approximately equal to A_0:

$$A_{op}(\omega \ll \omega_b) \approx A_0$$

For "large" frequencies, the math gets simple

Likewise, for frequencies **much greater** than the break frequency, we find that $\omega/\omega_b \gg 1$ and thus this gain is approximately equal to:

$$A_{op}(\omega \gg \omega_b) = \frac{A_0}{1 + j\left(\omega/\omega_b\right)} \approx \frac{A_0}{j\left(\omega/\omega_b\right)} = -j\,\frac{A_0\omega_b}{\omega}$$

But, we recall that the **product** of the op-amp D.C. **gain** A_0 and the op-amp **bandwidth** ω_b is the **gain-bandwidth product** ω_t (aka the unity gain frequency).

Thus, we can likewise write the previous approximation as:

$$A_{op}(\omega \gg \omega_b) \approx -j\,\frac{A_0\omega_b}{\omega} = -j\,\frac{\omega_t}{\omega}$$

A useful approx. of the transfer function

Recall also that when the signal frequency is **equal** to the op-amp break frequency (i.e., $\omega = \omega_b$), the transfer function is:

$$A_{op}(\omega = \omega_b) = \frac{A_0}{1 + j\left(\omega/\omega_b\right)} = \frac{A_0}{1 + j}$$

such that $\left|A_{op}(\omega = \omega_b)\right| = A_0/\sqrt{2}$.

Expressed in terms of the **magnitude** of this complex transfer function, we can express these **approximations** as:

$$\left|A_{op}(f)\right| \approx \begin{cases} A_0 & \text{if } f \ll f_b \\ A_0/\sqrt{2} & \text{if } f \approx f_b \\ \dfrac{f_t}{f} & \text{if } f \gg f_b \end{cases}$$