

How to Determine the Op-Amp Open-Loop Output Impedance

Applying phase compensation to amplifier circuits using op-amps requires knowledge about the open-loop output impedance of the device, Z_O . As this parameter is rarely specified in datasheets, this application note explains one of many ways to determine Z_O for a given capacitive load condition.

Loading the output of the non-inverting amplifier in Figure 1 with a large capacitance causes a gain peak in the frequency response. This is because C_L forms a pole with Z_O at frequency f_p , causing the unload open-loop gain, A_{ul} , to change its roll off from -20 to -40dB/decade (Figure 2). This section is denoted as the loaded open-loop gain, A_{ld} . At the frequency, where the closed-loop gain, $1/\beta$, crosses A_{ld} , the gain peak occurs. Therefore, this frequency becomes the peak frequency, f_{pk} .

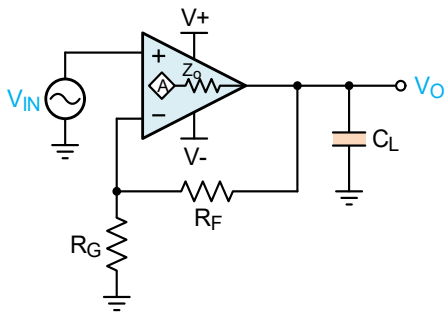


Figure 1.

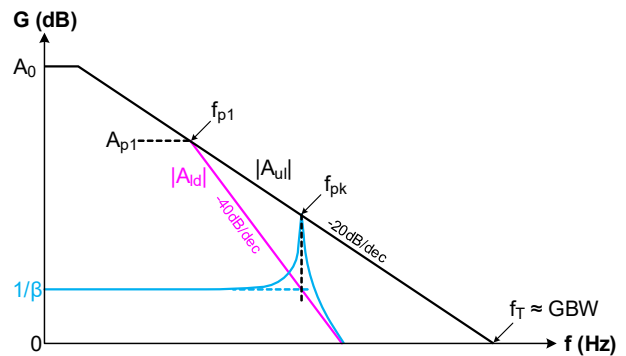


Figure 2.

To find the value for Z_O under this load condition, only two parameters must be known by the designer: f_{pk} , which can be measured with a network analyzer or oscilloscope, and f_T , which is the unity-gain bandwidth of the op-amp, and in most cases also the gain bandwidth, $f_T \approx \text{GBW}$.

As the open-loop gain at f_{p1} , denoted as A_{p1} , is equal for both roll offs, you can establish the constant gain-bandwidth equation for each slope:

$$\text{for the -20dB/dec roll off: } f_{p1} \cdot A_{p1} = f_T \Rightarrow A_{p1} = \frac{f_T}{f_{p1}}$$

$$\text{for the -40dB/dec roll off: } f_{p1}^2 \cdot A_{p1} = f_{pk}^2 \cdot 1/\beta \Rightarrow A_{p1} = \frac{f_{pk}^2}{f_{p1}^2 \cdot \beta}$$

$$\text{Setting both } A_{p1} \text{ terms equal and solving for } f_{p1}, \text{ gives: } f_{p1} = \frac{f_{pk}^2}{f_T \cdot \beta}$$

Then, substituting f_{p1} with $1/(2\pi Z_O C_L)$ and solving for Z_O , provides the open-loop output impedance:

$$\text{(EQ. 1) } Z_O = \frac{f_T \beta}{2\pi f_{pk}^2 C_L} \quad \text{with} \quad f_T \approx \text{GBW} \quad \text{and} \quad \beta = \frac{R_G}{R_G + R_F}$$

Revision History

Revision	Date	Description
1.00	May 10, 2022	Initial release.

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